

# New Scientist

WEEKLY 5 December 2015

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New guise for missing cosmic matter

**GENDER MYTH BUSTED**

No such thing as male and female brains

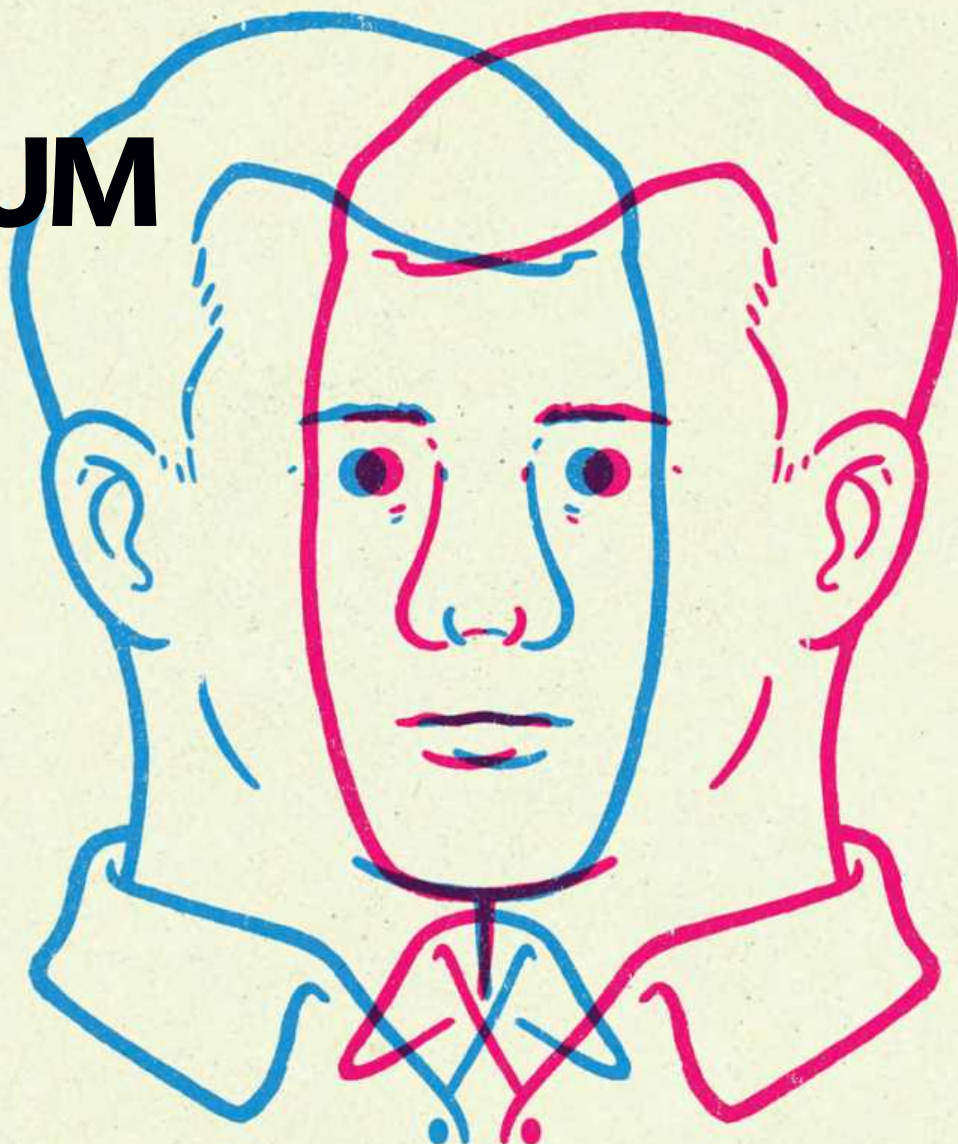
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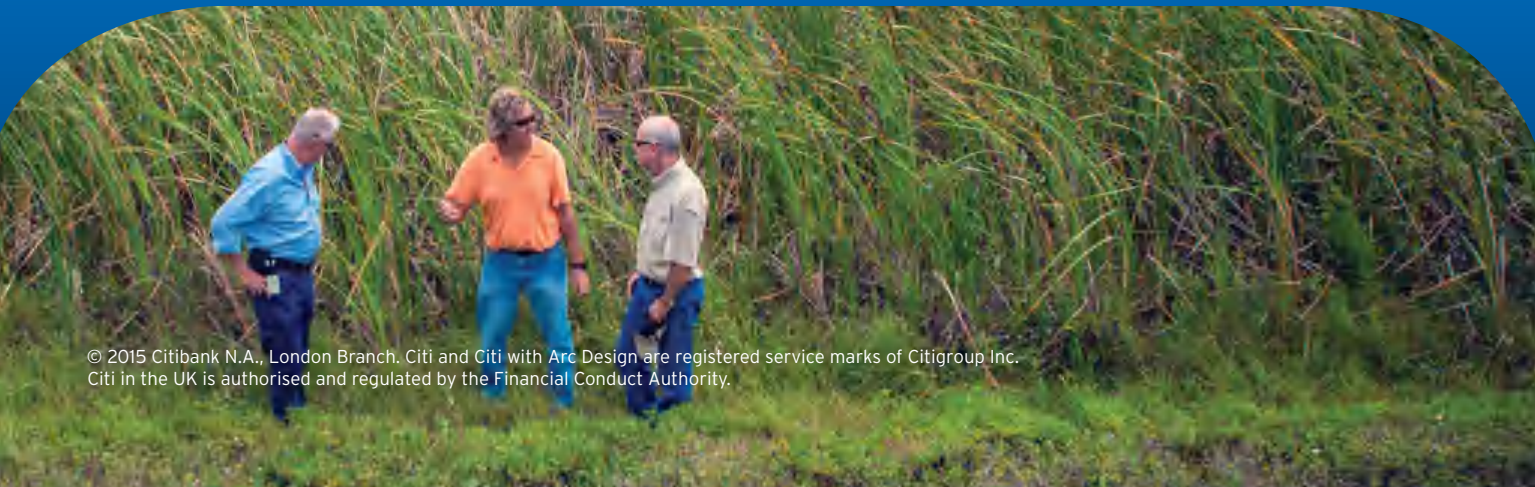


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There is no such thing as a male or female brain

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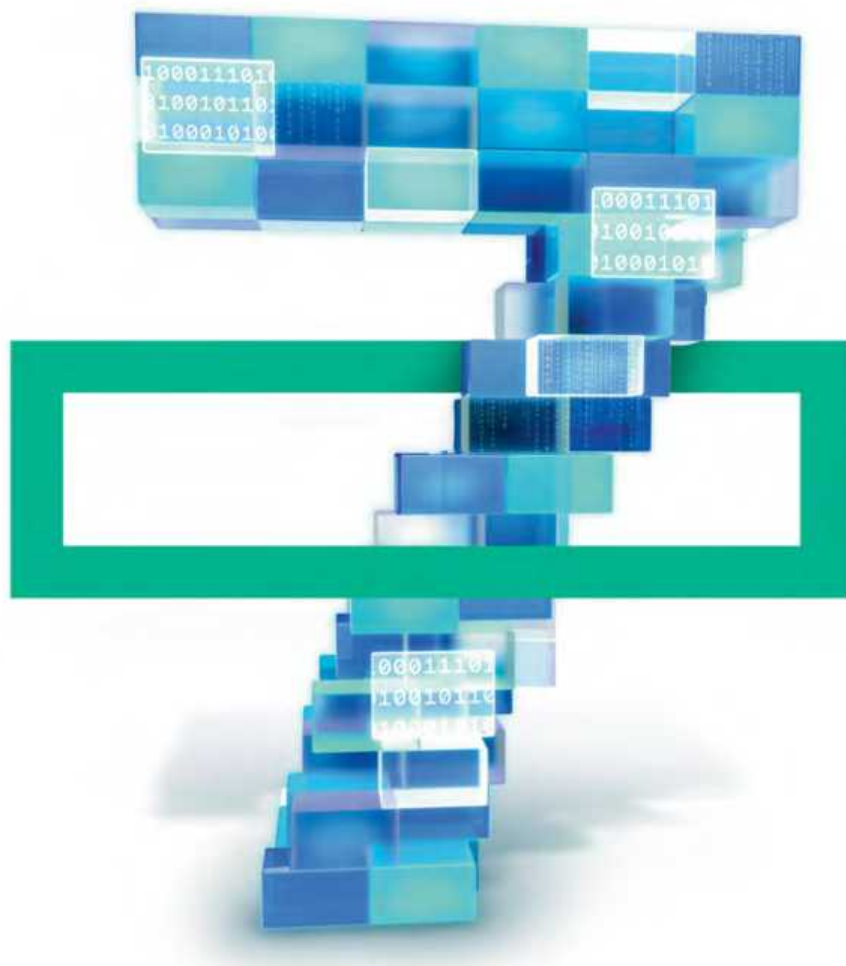
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# A chance to make amends

Timely conference on gene editing must learn from history

ALL eyes may be on the Paris climate talks, but there is another high-level meeting this week that will influence our future. The International Summit on Human Gene Editing in Washington DC is spending three days discussing the science, ethics and governance of a revolutionary genetic engineering technique called CRISPR – specifically its application to human beings.

The symposium was called by scientists, but will also hear from policy-makers, legal scholars and bioethicists. Its aim is to discuss what is acceptable, as well as what is possible.

This debate is timely, maybe overdue. In theory, we've had the ability to genetically engineer humans for decades. In practice, the methods haven't been good enough. But CRISPR has changed the game completely (see page 32).

Everyone in the field agrees on one thing: it is too soon to try this in people. Animals modified by CRISPR appear perfectly normal, but it's early days. Yet, there is a real danger that IVF clinics will attempt to use it. In some countries, including the US, this would not be against the law.

So what should we do? The meeting is not the first call to action. In October, a UNESCO bioethics panel recommended

a temporary ban on "engineering of the human germline, at least as long as the safety and efficacy of the procedures are not adequately proven". Early this year, a few researchers went further, calling for a temporary ban even on basic research.

The impulse to ban is understandable, but would be counterproductive. Basic genetic research on human embryos already happens in many

**"The ethics of embryo research should always be up for debate, but CRISPR hasn't changed the terms"**

countries. Stopping scientists from using CRISPR would deny them access to the most powerful tool yet to do what they already do. The ethics of embryo research should always be up for debate, but the existence of CRISPR has not changed the terms.

Some oppose basic research because the possible end point is altering heritable DNA. That needs to be, and is being, discussed. But banning CRISPR for that reason seems unnecessarily cautious.

"Possible" is not the same as "inevitable" or "acceptable". We could clone humans, but nobody does so, because there is an international consensus that

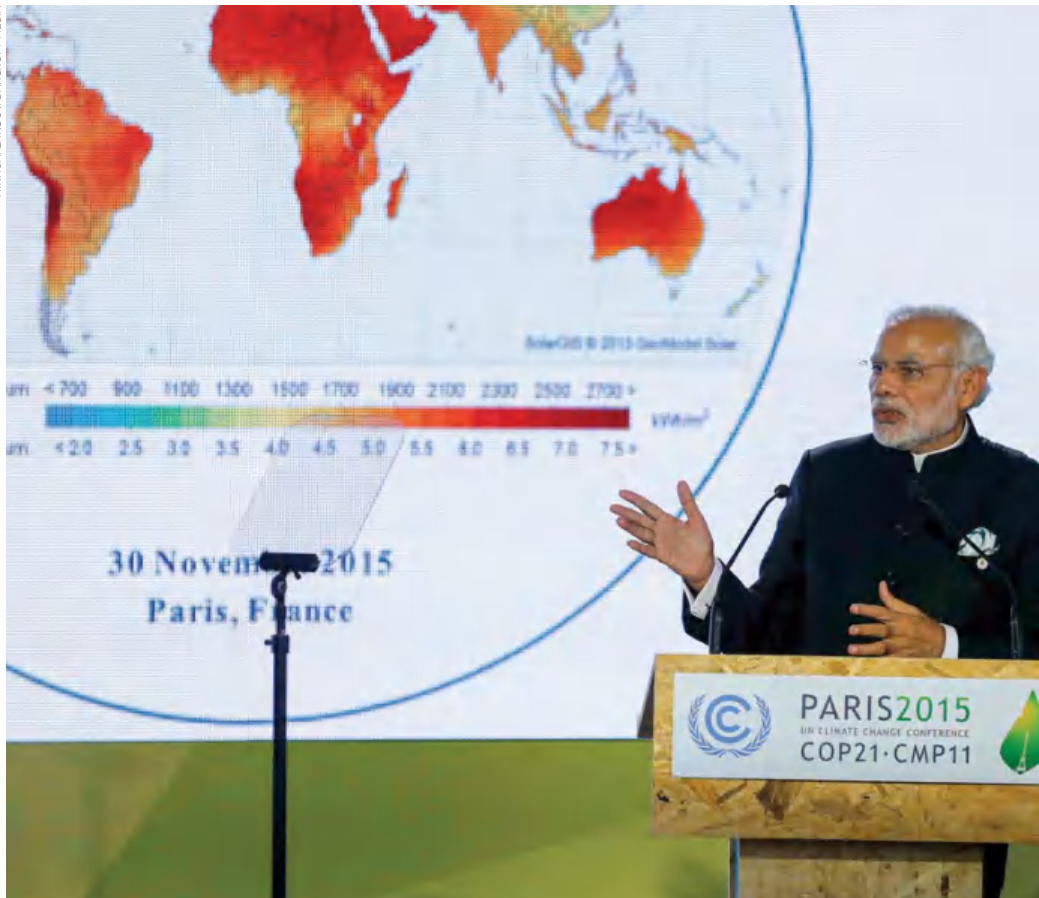
it is unethical. Engineering heritable germline DNA could be regulated the same way.

In any case, many would argue that using germline engineering to prevent some diseases is acceptable. We already use gene therapy to fix faulty genes in children – why not intervene earlier and prevent them ever becoming ill? Critics argue that there could be unknown dangers. But that is precisely why we need basic research on embryos.

It is also worth pointing out that although germline genome editing is often portrayed as permanent, there is nothing to stop us using the same technique to correct any mistakes.

An even more controversial application of CRISPR is human enhancement, but the science is so far behind the hype that it is hardly worth worrying about.

The summit will inevitably invite comparisons to the 1975 Asilomar conference, at which the pioneers of genetic engineering agreed a moratorium on some experiments until their safety was established. The verdict on Asilomar is mixed; some say the moratorium did more harm than good. Some of its movers and shakers are behind this week's summit. Let's hope they learned from the experience. ■



## World leaders talk climate

"TACKLING climate change is a shared mission for all mankind," said China's president Xi Jinping. He was among nearly 150 world leaders and other representatives from 190 countries gathered in Paris to nail down a global deal to cut carbon emissions. The deal will be negotiated over the coming two weeks, including the crucial point of whether any agreements will be legally binding. But on the sidelines, other announcements are being made too.

On Monday, Indian prime minister Narendra Modi invited 120-odd nations to join a new International Agency for Solar Policy and Application, aimed at helping poorer countries in the tropics develop solar power. India is investing \$30 million to set up a headquarters and aims to raise a further \$400 million.

There were also pledges by 20 major economies to double investment in renewable energy research and development. The White House described Mission Innovation as "an initiative to dramatically accelerate public and private global clean energy innovation". A similar drive by industry groups - the Breakthrough Energy Coalition, spearheaded by Bill Gates - aims to commercialise and implement the breakthroughs that Mission Innovation produces.

There is a good chance of reaching a global agreement since, instead of cuts being imposed from the top down, countries will decide their own contributions, with each offering what they think is fair.

But the exact wording on the summit's overall aims could be tricky to agree on, such as whether to try to

keep warming below 2°C, or perhaps 1.5°C. Some scientists believe 1.6°C of warming is already locked in, that 2°C may be inevitable, and that the current pledges will bring us to 2.7°C. There is also likely to be debate on the date by which the world should aim to be carbon-neutral.

Despite this, 43 countries will sign a declaration urging the UN to adopt a 1.5°C target, and the V20 - the 20 countries most vulnerable to climate change - are expected to vote as a bloc, urging stronger global aims.

The talks follow a weekend in which people all over the world took to the streets, calling for strong action on climate change at the summit. According to campaign group Avaaz, 785,000 people joined marches in 175 countries - the largest ever climate march.

## Abortion judgment

ABORTION laws in Northern Ireland breach human rights legislation, Belfast's High Court ruled on Monday.

The judge, Mark Horner, found that banning abortions of fetuses with fatal abnormalities, or that were conceived as a result of sexual crime, is incompatible with the European Convention on Human Rights. However, the ruling does not change the existing law.

Abortion is legal in Northern Ireland only when a pregnancy is deemed to pose a real risk to a woman's life or her mental health. People who receive or perform illegal terminations can face life imprisonment.

**"People in Northern Ireland who receive or perform illegal terminations can face life imprisonment"**

Every year, hundreds of women from Northern Ireland pay to get abortions elsewhere in the UK, where abortions are legal until 24 weeks of pregnancy, provided that the procedure has the support of two doctors.

"That smacks of one law for the rich and one law for the poor," Horner wrote. He suggests that reforming the abortion laws may require a referendum to gauge public sentiment.

## Another dark look

A CHINESE rocket launch is about to give us a fresh look at dark matter. If all goes to plan, the Chinese Academy of Sciences will be putting the Dark Matter Particle Explorer (DAMPE) satellite into orbit on 17 December.

The probe will scour the cosmos for protons, electrons and gamma rays. This could reveal smoking-gun signals of dark matter, the mysterious stuff which makes up 80 per cent of the mass in the universe but can't be seen directly.



Two other space telescopes have glimpsed hints of its presence. One shows a glow from the galactic centre that may be caused by particles of dark matter colliding and then annihilating around the black hole there.

The other has detected more positrons – the antimatter sibling of electrons – than expected. This could be the result of dark matter being annihilated nearby, but might also be caused by nearby pulsars. DAMPE should be able to test which explanation is right, says team member Yizhong Fan from the Chinese Academy of Sciences in Nanjing.

## Action on sugar

STEP away from the soda. UK prime minister David Cameron has been urged to take “bold and brave action” following a report on child obesity by MPs that calls for a 20 per cent levy on sugary drinks and a ban on advertising junk food during family TV shows.

Some of the best evidence for the sugar tax comes from Mexico, where a 10 per cent levy on sugary drinks imposed in 2014 led to declines in purchases of up to 12 per cent.

But another of the report’s suggestions – to clamp down on unhealthy food and drink promotions in supermarkets – might be a more effective way to beat the bulge. A report published in October by Public Health England, a government agency, showed that price promotions such as “two for one” offers can increase sales of carbonated drinks by as much as 50 per cent.

“A full package of bold measures is required and should be implemented as soon as possible, with all proceeds clearly directed to improving our children’s health,” said Sarah Wollaston, Conservative MP and chair of the cross-party House of Commons health committee, which published its report this week.

## UK carbon setback

CHOP and it’s gone. The latest in a series of spending cuts will make it even harder for the UK to meet its own climate targets.

The country has set itself the goal, enshrined in law, of cutting emissions by 80 per cent by 2050, but had already strayed by the start of the year. Since then, it has halted numerous green initiatives, including slashing funding for onshore wind and solar, the cheapest forms of renewable energy.

Now the chancellor, George Osborne, has scrapped a £1 billion

plan to build a demonstration carbon capture and storage plant. Without CCS, the government would have to start shutting down fossil fuel power stations and heavy industries in the 2030s to have a chance of meeting targets.

**“Without carbon capture and storage the chances of meeting emissions targets are much smaller”**

But the other cuts mean it is not likely to be in a position to do this. One piece of good news was that the UK’s research budget was largely spared the feared cuts.

## Yorkshire ripper to move to jail?

SERIAL killer Peter Sutcliffe should be transferred from hospital to jail, according to the UK’s national offender management service. This Ministry of Justice agency told MPs they have advice from doctors that Sutcliffe may be moved to a specialist prison unit. Why has it taken 31 years and millions of pounds to come to this decision?

Known as the “Yorkshire Ripper”, Sutcliffe was sentenced to multiple life terms in 1981 for the murder of 13 women. Three years later, he was diagnosed with paranoid schizophrenia and sent to Broadmoor High Security Psychiatric Hospital, near Bracknell, UK.

Patients in Broadmoor are often moved to a lower-security hospital or

prison within five years. Most people with paranoid schizophrenia have full or partial remission after a year of treatment, says Tony Maden, former head of the Dangerous Severe Personality Disorder unit at Broadmoor. However, people who don’t respond to treatment can stay in Broadmoor for longer.

Maden questions why Sutcliffe has stayed at Broadmoor for so long, which costs more than £300,000 per patient per year. “My concern is that what’s led to Sutcliffe being kept there for so long is notoriety,” says Maden. “It’s difficult to look at this as a good use of resources for the NHS.”

The final decision over any move will be made by the justice minister, Michael Gove.



An expensive stay

## 60 SECONDS

### Whale of a task

Japan’s whaling fleet set sail for the Antarctic this week. It is aiming to kill 333 minke whales for what it claims is scientific research in the country’s first hunt for two years. Japan was ordered to stop whaling in March 2014 by the UN International Court of Justice, but has decided unilaterally to defy the ruling.

### Rhino horns legal again

It’s legal to sell rhino horns again in South Africa after a judge lifted a 2009 ban on trade, ruling in favour of two private rhino breeders. Edna Molewa, the country’s environment minister, vowed to appeal against the decision, which could undermine the global ban on trade in rhino horns.

### Driller thriller sets sail

Mantle, here we come. For the first time, geologists are hoping to drill through Earth’s crust to reach its boundary with the underlying mantle, which could harbour microbial life. A team set sail this week aboard the JOIDES Resolution research ship for a drill site in the Indian Ocean where the crust is unusually shallow.

### Space-station supply

You can’t keep a good spacecraft down. On 3 December, Orbital ATK is set to launch its first Cygnus supply craft to the International Space Station since October last year. The previous one was destroyed when its Antares rocket blew up on launch. This time, Orbital will use an Atlas V launch vehicle from fellow rocket firm United Launch Alliance.

### Organ opt-out

Wales has become the first country in the UK to introduce an opt-out system for organ donation. Unless they opt out, adults living in Wales will be presumed to have given consent for their organs to be donated when they die. This is expected to boost the supply of donated organs by a quarter.

JOHN ROGERS/CAMERA PRESS

# Brains are not male or female

First sex analysis of the whole brain suggests gender distinctions are often meaningless

Jessica Hamzelou

YOU may have read that having a male brain will earn you more money. Or maybe that female brains are better at multitasking.

But there is no such thing as a female or male brain, according to the first search for sex differences across the entire human brain. Scans of 1400 brains reveal most have a mix of male and female features. The work also supports the idea that gender is not binary,

**“The study gives biological support to something we’ve known for some time - gender isn’t binary”**

and that gender classifications in many situations are meaningless (see Comment, far right).

“This evidence that human brains cannot be categorised into two distinct classes is new, convincing, and somehow radical,” says Anelis Kaiser at the University of Bern, Switzerland.

The idea that people have either a “female” or “male” brain is an old one, says Daphna Joel at Tel Aviv University in Israel. “The theory goes that once a fetus develops testicles, they secrete testosterone which masculinises the brain,” she says. “If that were true, there would be two types of brain.”

To test this, Joel and her colleagues looked for differences in brain scans taken from 1400 people aged between 13 and 85. The team looked for variations in the size of brain regions as well as the connections between them. Overall, they identified 29 brain regions that generally seem to be

different sizes in people who self-identify as male or female. These include the hippocampus, which is involved in memory, and the inferior frontal gyrus, thought to play a role in risk aversion.

When the group looked at each individual brain scan, however, they found that very few people had all of the brain features they might be expected to have, based on their sex. Across the sample, between 0 and 8 per cent of people had “all-male” or “all-female” brains, depending on the definition used (*PNAS*, doi.org/9k4). “Most people are in the middle,” says Joel.

This means that, averaged across many people, sex differences in brain structure do exist, but an individual brain is likely to be just that: individual, with a mix of features. “There are not two types of brain,” says Joel.

Although the team only looked at brain structure, and not function, their findings suggest



that we all lie along a continuum of what are traditionally viewed as male and female characteristics. “The study is very helpful in providing biological support for something that we’ve known for some time – that gender isn’t binary,” says Meg John Barker,

a psychologist at the Open University in Milton Keynes, UK.

The findings will still come as a surprise to many, including scientists, says Bruce McEwen at the Rockefeller University in New York. “We are beginning to realise the complexity of what we have traditionally understood to be ‘male’ and ‘female’, and this study is the first step in that direction,” he says. “I think it will change people’s minds.”

## Cultural expectations

Markus Hausmann at Durham University, UK, isn’t surprised by the findings, however. He has been studying sex differences in cognition, such as whether men, as commonly believed, really do have better spatial awareness.

“Across all kinds of spatial skills, we find very, very few that are sensitive to sex,” says Hausmann. “We have also identified spatial

## GENDER MYTHS

**Plenty of gender stereotypes have little evidence.**

### MEN ARE OBSESSED WITH SEX

Many studies have found that men report having more casual sex than women. But female sexual appetites may be underestimated because women are more likely to downplay use of pornography or masturbation, while men tend to exaggerate theirs.

### WOMEN ARE BIGGER GOSSIPS

We’ve all heard that women are better communicators. In reality, the

gender differences in verbal abilities are small, and for some specific skills, men outperform women. Some studies find that girls are better at reading, but it might only seem that way because boys are more likely to have learning difficulties.

### BOYS ARE BETTER AT MATHS

A large meta-analysis of 242 studies found that girls and boys are equally competent when it comes to maths. Tellingly, girls tend to perform as well as boys in countries with more gender equality.



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Not so different

problems where women outperform men; the black-and-white idea of a male or female brain is clearly too simple."

Despite persisting stereotypes, girls are no worse than boys at science and maths subjects, either (see "Gender myths", left). "People get wedded to the idea that being male or female is highly predictive of having different aptitudes or career choices," says Margaret McCarthy at the University of Maryland in Baltimore. "This study fights against the idea that these outcomes are based on biological differences, as opposed to cultural expectations."

Some other parts of the body, such as the immune system, are also often wrongly considered to be either male or female, says Joel.

Alexandra Kautzky-Willer, head of the Gender Medicine Unit at the Medical University of Vienna in Austria, agrees that things

aren't so simple. "There are differences between men and women when you look in large groups, and these are important for diagnosis and treatment," she says. "But there are always more differences within genders. We always need to look at culture, environment, education and a person's role in society," she says.

## Genderless future

If a neuroscientist was given someone's brain without their body or any information, they would still probably be able to guess if it had belonged to a man or a woman. Men's brains are larger, for example, and are likely to have a larger number of "male" features overall. But the new findings suggest that it is impossible to predict what mix of brain features a person is likely to have based on their sex alone.

Joel envisions a future in which individuals are not so routinely classified based on gender alone. "We separate girls and boys, men and women all the time," she says. "It's wrong, not just politically, but scientifically – everyone is different."

But other scientists contacted by *New Scientist* don't think that will ever be possible – as a sexually reproductive species, identifying a person's biological sex will always be of paramount importance to us, they say.

Even so, Joel's findings can be used to help people understand the non-binary nature of gender, says Barker. After all, some people don't identify as either male or female, and others feel their gender identity shift over time. "It's a shame that people's experience alone isn't enough for us to recognise as a society that non-binary gender is legitimate."

"We need to start thinking a lot more carefully about how much weight we give to gender as a defining feature of human beings, and stop asking for it in situations where it simply isn't relevant," says Barker. ■

## COMMENT

# Greetings, Earthlings

This blow to the myth of distinct male and female brains is welcome, says **Gina Rippon**



ASTON BRAIN CENTRE, ASTON UNIVERSITY

A KEY barrier to equality is crumbling, thanks to a new imaging study (see left), which blows away the idea that male and female brains are distinct.

It means the power of neuroimaging to explore and explain links between brain and behaviour can at last come into its own, but free of the constraints of preconceived stereotypes. Our understanding of sex-related brain differences will move beyond simple and outdated dichotomous thinking.

Knowing the controversy associated with such declarations, the study's authors, led by Daphna Joel, used several datasets from different laboratories and investigated the veracity of their findings using more than a single neuroimaging measure.

The work adds to similar discussions in neuroscience and to recent research that finds earlier "well-established" sex differences in brain structures turn out to be false on careful reanalysis.

And it gels with the broader idea that the biology of sex differences is not what we thought. *Nature* last year reported data showing that, even in the most fundamental aspects of sexual differentiation, including chromosomes, cells and genital anatomy, thinking in simple male/female terms is no longer tenable.

What's more, for several years, psychologists have been saying that,

in terms of cognitive skills and personality characteristics, the "two" sexes are more similar than different. Just knowing whether someone is male or female is a very poor predictor of almost any kind of behaviour.

Most recently, researchers showed that, on over 100 different behavioural measures, male and female scores could not be reliably – or accurately – grouped into two distinct categories.

Joel's paper is also timely. In the US, the National Institutes of Health has mandated the inclusion of both sexes in preclinical and clinical research and some European funding is predicated on inclusion of sex and gender factors.

This means we are also likely to see greater emphasis on statistically based sex "differences", which may be misinterpreted as evidence of the kind of non-overlapping dichotomies that Joel's study contradicts. Many researchers point out that these

**"This finding gels with the broader idea that the biology of sex differences is not what we thought"**

statistical categories are at best fallacious, at worst possibly harmful.

This is a controversial area and can lead to entrenched positions. But neuroscientists must now re-examine the design and interpretation of their research, the conclusions they draw and how they are communicated.

Continuing to think in terms of simple male-female distinctions is flying in the face of the evidence and will lead to poor research and misleading findings. To paraphrase the title of a key paper in this area, men are not from Mars or women from Venus, we are all from Earth. ■

Gina Rippon is a professor of cognitive neuroimaging at Aston University, UK

# Hunt is on for quark dark matter

Anil Ananthaswamy

A RETHINK could reveal the secrets of dark matter. The mysterious particles that make up most of the unseen mass of the universe have evaded physicists for decades. But it seems they may have been looking for the wrong thing.

A new hypothetical particle, related to the fundamental quarks found inside protons and neutrons, has popped out of a model originally developed to solve a separate mystery in physics. This could be the missing dark matter. What's more, the Large Hadron Collider (LHC) – the particle smasher at CERN near Geneva, Switzerland – could find evidence for it in a few years.

Astronomers think that dark matter exists because of rapidly rotating galaxies, which would

have long since disintegrated without the gravitational pull of an invisible mass.

The favoured candidate for dark matter is a hypothetical particle called the neutralino. This comes from supersymmetry, a theory that solves some niggling problems with the standard model of particle physics by doubling the number of particles.

The neutralino is neutrally charged and only meaningfully interacts with other particles gravitationally – exactly the properties of dark matter. But if the simplest models of supersymmetry are correct, we should probably have seen some evidence of it at the LHC. Yet there hasn't been even the faintest hint.

"Neutralino dark matter looks contrived or challenged," says Mark Wise of the California Institute of Technology

in Pasadena.

Now Bartosz Fornal and Tim Tait of the University of California, Irvine, have stumbled on another possibility while trying to solve an unrelated puzzle: why the proton, one of the particles inside atoms, is stable.

Many particles in the standard model decay into others, but some don't because of the laws of conservation. The electron, for example, is the lightest charged

**"You try to solve a different problem and you end up finding dark matter staring you in the face"**

particle and cannot decay to something lighter without destroying charge.

No existing conservation law prevents a proton from decaying, but physicists are yet to see it happen. Current estimates say the proton must live for at least  $10^{34}$  years – but our universe is only about  $10^{10}$  years old.

Fornal and Tait wondered whether an unknown conservation law could be preventing proton

decay, and turned to a property called the baryon number.

"The baryon number seems to be conserved, though we don't really understand why," says Tait. For example, the conservation of charge is related to the electromagnetic force. So to give the baryon number a similar status, Fornal and Tait decided to associate it with a new force.

The pair hypothesised this force by first positing a superforce that exists only at the high energies present instants after the big bang. As the universe cooled, the unified force split into two distinct forces: one for the baryon number and the other being the strong nuclear force, which binds quarks together to create protons and neutrons.

There was a surprise in store. To make the unification work, the pair had to add new particles – the properties of which were predicted by the model. "When you do that, the theory automatically contains dark matter," says Tait. "You try to solve a different problem and you end up finding dark matter staring you in the face."

The new model requires quarks to have heavier partners, and the lightest of these has the right properties to be dark matter. For instance, these particles would have been made in about the right amount in the early universe to explain the dark matter we see today ([arxiv.org/abs/1511.07380](https://arxiv.org/abs/1511.07380)).

"It's exactly the kind of cool, risky idea that I think is most interesting," says LHC researcher Daniel Whiteson, also of UC Irvine. He is already making plans to verify the model's predictions. Although the LHC is not powerful enough to create the dark matter particles hypothesised by the model, it could, within the next few years, create particles related to the new unified force.

"Some ideas just feel like they are on the right track; this is one of those," says Wise. "However, nature will do what nature does and it's up to experiment to be the final judge." ■



Press green to find particles





Let's get cracking

## Huge crack forces early move for Antarctic base

LIFE on a floating ice shelf is precarious enough, but when a massive crack is heading your way, you know you're in trouble. This nightmare scenario is what's forcing the UK's newest research station in Antarctica to relocate.

Halley VI opened in 2013 to much fanfare due to its space-age design. It's built as eight modules on skis so that it can be towed to a new location if the ice conditions change.

The British Antarctic Survey (BAS) research station has been gathering atmospheric data since 1956 – measurements from Halley led to the discovery of the hole in the ozone layer in 1985. It is located on the Brunt ice shelf, a floating slab of ice some 150 to 250 metres thick attached to the Antarctic landmass and extending out into the sea.

All five of Halley's predecessors had to be abandoned after becoming buried in the snow or getting too close to the edge of the shelf. But the threat now facing Halley VI is different.

Ice shelves commonly feature crevasses. Extremely large cracks

occasionally form when the shelf breaks in the summer but then partially heal in the winter as the sea freezes and snow accumulates. These cracks sometimes begin to grow again, which can lead to vast icebergs breaking off into the ocean.

This happened in 1998, when a huge section of the nearby Filchner-Ronne ice shelf broke off, creating a massive iceberg 144 kilometres long and 48 km wide with the unoccupied German base Filchner trapped on top. And in 2013, a massive iceberg the size of New York City calved off at Pine Island Glacier on the opposite side of the Antarctic.

"All ice shelves do this. It's a natural event," says Hilmar Gudmundsson, a glaciologist at the BAS. "But it's difficult to say exactly when and how large these events will be. It's a bit like trying to predict an earthquake."

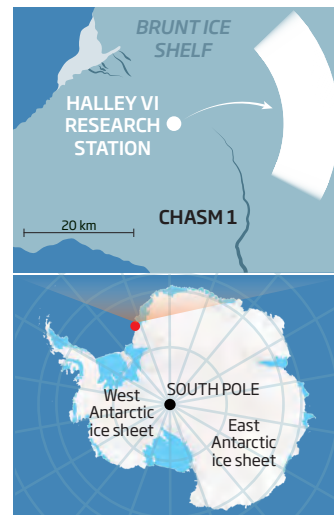
The Brunt ice shelf has a number of prominent cracks, including one called Chasm 1. It's a massive feature – more than 50 m deep, 30 km long and 1 km wide in parts – that formed 30 years ago

but remained dormant. Then, in 2012, the area round the tip of the chasm began to change and satellite measurements confirmed that the crack had started to grow. It's not clear why this happened, but Gudmundsson says there is no evidence that it is related to global warming.

The crack is extending in the direction of Halley VI at a rate of 1.7 km a year, and is 8 km away

### Relocation, relocation

A chasm in the Brunt ice shelf in Antarctica is heading towards the UK's Halley Research Station, forcing it to relocate 20-30 km away



from the base. "We don't know what will happen," says Gudmundsson. "It might stop growing, but we can't exclude the possibility of a big calving event."

The main concern is that Chasm 1 will grow so much that it makes it impossible to relocate

**"It's difficult to say when or how large iceberg calving events will be. It's like predicting an earthquake"**

the base in the future. That's why a move is now underway.

The station has recently begun its brief summer season after nine months of winter isolation, and during this time, preparations will be made for the move. The bulldozers needed to tow the modules will be brought in by ship in the coming months – assuming it can get through the heavy sea ice common here. If all goes to plan, the relocation will take place in a year's time.

"We'll break down the base into individual modules and each will be towed to a new site. That's the simplistic version anyway," says Adam Bradley, Halley's station leader. The move is going to be complex and costly, with many technical challenges. For example, the modules are so heavy that even small slopes pose an issue, so the route must be carefully chosen. "One of the jobs is to define the maximum slope angle that we can tow these things up," Bradley says.

The exact location of Halley VI's new home will be decided in a few months after extensive surveys of the terrain have taken place, but it will be on the other side of Chasm 1, perhaps 20 to 30 km away. "That gets us into a safer zone," says Bradley. But this site will bring new logistical challenges, as it's further from the coast and all supplies arrive by ship.

Until the base can be moved, however, Gudmundsson will be keeping a close eye on Chasm 1, via satellite images and GPS.

Alison George ■



Legs good, but brains?

# Runners' joints self-heal on the go

Jessica Hamzelou

KEEP on running. Ultramarathons do take a toll on a runner's body, breaking down cartilage and even shrinking the brain, but athletes seem to bounce back from both, with joints repairing before the race has even finished.

For many, marathons represent the ultimate fitness challenge. But a minority go much further, taking part in ultramarathons like the Trans Europe Foot Race, covering

4500 kilometres from the south of Italy to Norway in 64 days.

This race equates to around 100 marathons, with no rest days, prompting researchers to wonder what such long periods of intense exercise would do to the body.

Uwe Schütz at the University Hospital of Ulm in Germany and his colleagues have spent the last six years finding out. In 2009, they followed a group of 44 runners as they ran the nine-week race across Europe. The team

took a portable MRI scanner with them, and periodically scanned the legs, feet, heart, brains and cardiovascular systems of the athletes, as well as taking blood and urine samples.

Scanning feet and leg joints every 900 kilometres, Schütz and his team measured the amount of water that was released from the shock-absorbing cartilage between the bones – a sign of whether cartilage is breaking down. They found that the runners' cartilage seemed to degrade during the first 2500 km of the race.

But after that distance – around 60 marathons – the cartilage seemed to recover, says Schütz, who presented the findings at the

Radiological Society of North America annual meeting in Chicago this week. "It was thought that cartilage could only regenerate during rest," he says. "We have shown for the first time that it can regenerate during running."

A runner's joints aren't the only parts of their body affected. Earlier analyses of the same runners revealed that their brains seemed to temporarily shrink in size by 6 per cent over the course of the race.

The loss may simply be the result of extreme fatigue and undernourishment, but Schütz thinks it could be caused by lack of stimulation. One of the four brain regions that seems to be particularly affected is known to be involved in visual processing. That area may have been massively under-stimulated by 64 days of viewing little other than roads, he says.

Others have suggested that athlete's brains may reorganise themselves to divert energy to regions involved in motivation. "It is hard to explain what's going on," says Schütz. "But we do see total recovery after six months."

Schütz says people who run normal marathons won't experience the same degradation.

Aerobic exercise is generally beneficial for the brain, helping to stave off depression and dementia. ■

## Encrypt secrets in the afterglow of the big bang

IF YOU'VE got a message to keep safe, look to the skies. You could use the afterglow of the big bang to make encryption keys – all you need is a radio telescope.

The security of many systems relies on generating large random numbers to act as keys to encrypt information. Computers can use algorithms to spawn these keys, but they aren't

truly random, so another computer armed with the same algorithm could potentially duplicate the key.

An alternative is to rely on physical randomness, like the weather, the thermal noise on a chip or the timing of someone's keystrokes. Now Jeffrey Lee and Gerald Cleaver at Baylor University in Waco, Texas, have taken this to the extreme by suggesting we use the thermal radiation left over from the big bang – the cosmic microwave background.

There are several ways to extract numbers from the CMB. For example, you could divide a patch of sky into

pixels and measure the strength of the CMB's radio signal, which is never duplicated exactly. Over time, each pixel would generate a string of different strengths, which are just numbers. Putting the strings together gets you a very large random number ([arxiv.org/abs/1511.02511](https://arxiv.org/abs/1511.02511)).

"An adversary measuring the same patch of sky exactly the same way and at exactly the same time could not get

**"Someone measuring the same patch of sky exactly the same way could not get the same values"**

exactly the same values," says Lee.

Mads Haahr of Trinity College Dublin in Ireland runs a website called [random.org](https://random.org), which uses noise from weather to generate random numbers. He says the big issue with CMB encryption would be setting up a radio telescope to get a key.

Lee agrees this is not something individuals can do, and it might not offer better encryption than the weather. But, he says, "it brings together two fields of study that don't often cross-pollinate – early universe cosmology and cryptography". Jesse Emspak ■



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**Go Further**

INSIGHT HIV pills on demand

# Anti-HIV drug splits opinion

Clare Wilson

HELPFUL or harmful? A drug that you can take before and after sex can help people cut their risk of HIV infection.

Men and women in the US can already take the drug as a daily pill. The new “on demand” regime could make the drug more convenient, and cheaper to use regularly, yet not everyone is convinced. Some doctors fear the approach will discourage condom use, while others, such as Michael Weinstein of the AIDS Healthcare Foundation, see it as

**“If anything I use condoms more than I did before - taking Truvada reminds you you’re not infallible”**

a free pass to promiscuity.

We should abandon such moralising for the sake of public health. “This will be a powerful tool for almost eliminating HIV transmission,” says Cécile Tremblay at the University of Montreal, Canada. “If we combine it with other measures we could reach that goal in developed countries within 10 years.”

The medicine in question is called Truvada. It contains two antiviral drugs, tenofovir and emtricitabine, also given to people infected with HIV, which stop the virus multiplying. Tremblay and her colleagues followed 400 gay men over nine months and showed that the drug reduced risk of infection by 86 per cent when taken just before sex and for two days after, and so was just as effective as the daily pill (*NEJM*, doi.org/9mb).

On the face of it, having any kind of unprotected sex seems

risky. Yet Truvada users are making highly nuanced decisions about their risks, argues Sheena McCormack of University College London, who helped run a trial of daily Truvada.

In the West, such pre-exposure prophylaxis, or PrEP, has mainly been studied in gay men. Most trial participants used condoms some of the time, only forgoing them when it seemed safe, after asking their partners when they were last tested and when they’d had unsafe sex (see “Why I don’t always use condoms”, below).

PrEP may paradoxically reduce risk-taking in some. “If anything, I probably use condoms more now,” says Colby Briggs, a project manager at McGill University in Montreal. “Taking Truvada reminds you that you’re not infallible.”

One trial of daily Truvada showed that the drug did reduce condom use, yet STD rates stayed the same, perhaps because people were good at assessing their partner’s sexual history. It’s less clear how well PrEP works in people having heterosexual sex.

PrEP is not the only tool that we have for reducing the spread of



Another insurance policy

HIV. We could put everyone who has HIV onto antivirals, which can suppress the virus, making it less likely to be passed on. In theory, such universal treatment could eradicate HIV.

It’s an expensive goal: the World Health Organization’s aim of suppressing HIV in three-quarters of those infected by 2020 is unlikely to be met. Sub-Saharan Africa and the US have suppressed the virus in 30 per cent of those with HIV; the UK and Australia have reached 60 per cent.

Combine universal treatment with PrEP and we could reduce transmission much faster, says Tremblay. Yet access to PrEP is patchy. In the US, where Truvada has been licensed since 2012, a third of doctors have never heard of it. It’s also expensive: in the UK it costs about £400 for 30 pills.

Some people are inevitably buying it online for about a tenth of the cost. That’s a false economy for the UK’s National Health Service, says McCormack, because those users may not have the regular HIV tests that are a crucial part of PrEP. If people do get infected on PrEP, their virus can become resistant to the two drugs in Truvada and then spread to others.

In many other aspects of HIV prevention, Western countries have embraced “harm reduction”, accepting that risky behaviours cannot always be prevented but can be mitigated. So why can’t we expand that to PrEP? As Tremblay says: “If we have a way to protect people from catching what can be a deadly disease, then it’s immoral not use it.” ■

## ‘WHY I DON’T ALWAYS USE CONDOMS’

“I’m not phenomenal with condoms,” says Colby Briggs, a gay man in his twenties who lives in Montreal. “I use them about half the time.”

Briggs has taken part in a trial of Truvada, a drug that reduces his risk of contracting HIV. The drug can be taken daily or just before and after sex (see main article).

In common with many of the trial participants, his decision on whether or not to wear a condom is carefully considered. “I don’t ever have sex

with someone who I haven’t asked about their sexual history,” he says.

“People are very forthcoming, particularly if they do have HIV. They are often incredibly responsible.”

The times that Briggs does use condoms he still uses the drug. “Truvada has never been presented to me as a replacement to condoms,” he says. “It was always an insurance policy. Condoms aren’t perfect, they break, they fall off. This is an extra layer of security.”



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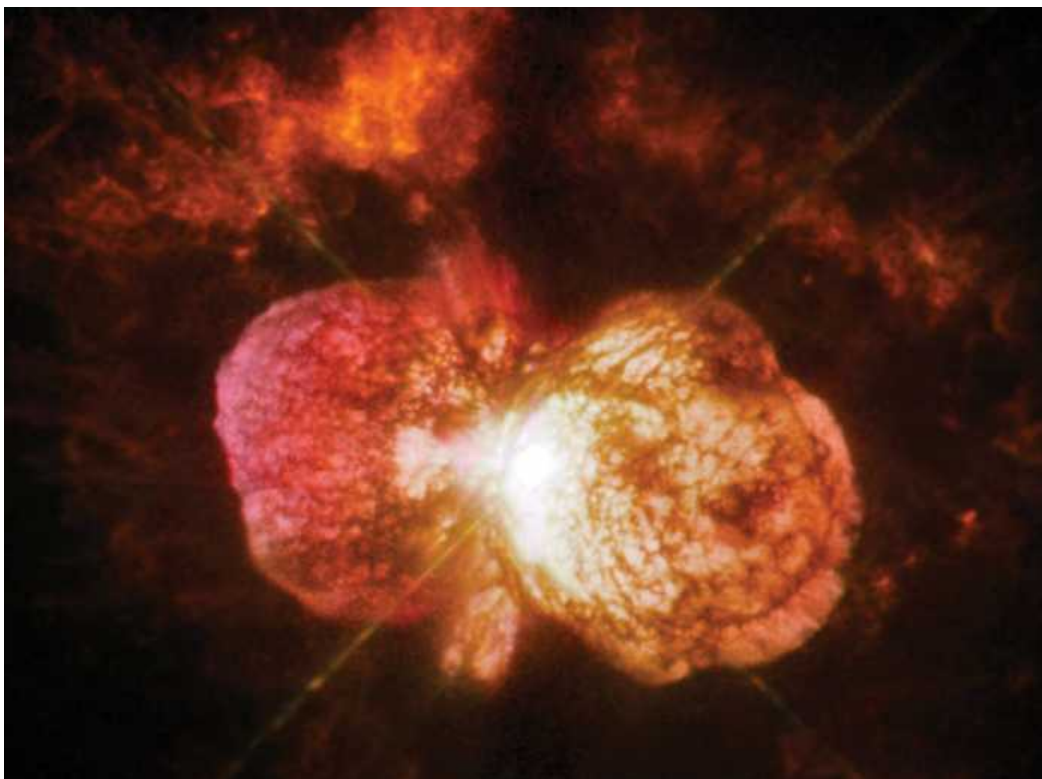
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## Ménage à star could explain the birth of Eta Carinae

IT IS one of our galaxy's biggest and most bizarre objects: a pair of stars, each much more massive than our own sun and shrouded in huge clouds of chaotic gas. Since the 19th century, astronomers have been puzzling over just how Eta Carinae came into being. Could a dramatic three-way encounter be the answer?

Observational records detail how Eta Carinae mysteriously rocketed in brightness in 1838 and again in 1843, when it dazzled as the second brightest star in the night sky before fading away. "It is different to anything we've ever seen before," says Simon Portegies Zwart of

Leiden Observatory in the Netherlands. Now he and Edward van den Heuvel of the University of Amsterdam believe they have solved the mystery of Eta Carinae's birth: the system started out as three stars, not two.

According to their model, the gravity of an outer star caused the two inner stars to merge. This not only bloated the atmosphere of the newly merged star, but also pulled the outer star inwards, giving us the close pair we see today. "The 1838 event was caused by the merger and the 1843 event when the outer star grazed the bloated layers of the inner star," says Portegies Zwart.

The squeezing together of the merging stars gave rise to a strong stellar wind, forming what's known as the Homunculus nebula, while the grazing event made unusual "skirts" in the gas (arxiv.org/abs/1511.06889).

## Can't kick the habit? Blame your genes

SOME people may have a get-out clause when it comes to giving up smoking. A third of white people who smoke have gene variations that make it harder for them to kick the habit.

A gene called *ANKK1* regulates the release of dopamine – a chemical involved in the brain's reward centres. Ming Li at the Zhejiang University School of Medicine in Hangzhou, China,

wondered whether variations of this gene might affect people's ability to give up cigarettes. So his team analysed 22 studies that have linked *ANKK1* to smoking, involving 9487 white participants.

The team found that two-thirds of white smokers carried a variation of the gene called *A2/A2*. These people were 22 per cent more likely to be able to quit smoking than those who carried

an alternative version of the gene called *A1/A1* or *A1/A2* (*Translational Psychiatry*, DOI: 10.1038/tp.2015.176).

People carrying these versions of *ANKK1* may need more aggressive strategies to fight their addiction to cigarettes, says Li.

The *A1/A1* and *A1/A2* gene variations have also been linked to obesity and drug addiction, which suggests they may predispose people to addictive behaviours.

## Tilted planet knocks out theory

IT'S all gone pear-shaped. A new off-kilter exoplanet is threatening our best theory on why some gas giant orbits are wonky.

Big gas planets, known as hot Jupiters, can orbit close to their stars at all sorts of weird angles. Stars and their planets grow out of the same spinning disc, which means that something extra – such as interstellar gas or magnetic fields – causes the tilt.

Hot Jupiters around smaller, colder stars orbit in the same plane as the star, so it was thought that a tidal gravitational force between the thicker atmosphere and the planets keeps the planets in line. A recently discovered planet challenges that idea, says George Zhou at the Australian National University in Canberra.

HATS-14b tightly circles a small star, but its orbit is a whopping 76 degrees away from the plane of its star's spin. This knocks out the tidal theory (arxiv.org/abs/1510.08575).

## Cancer's genomic tipping point

MUTATE, but not too much. Cancer has an optimum level of genomic diversity, beyond which it becomes less deadly.

The chromosomes of cancer cells undergo rearrangements and mutations that help it grow and spread. Carlo Maley of Arizona State University and colleagues sequenced the genomes of 1165 tumours and found an optimum level of genomic instability, beyond which the cancer became less aggressive, and people survived longer (*Nature Medicine*, DOI: 10.1038/nm.3984).

Chemo and radiotherapy turned out to be most effective on cancer at this level. These treatments induce more mutations in cancer cells, so are likely pushing them past the optimum, says Maley.



## Leg gushes blood in gory simulation

**OUCH!** A detailed simulation of a human leg injured by flying shrapnel, gushing blood and all, could help train medics for real combat situations.

The video simulation was created by Jeff Eldredge at the University of California, Los Angeles, and his colleagues. The main challenge was to solve the governing equations of fluid dynamics and tissue mechanics to show exactly what happens with real injuries. The virtual leg has realistic bone, muscle and skin, along with a vascular system that drives the flow of blood gushing out of damaged arteries and veins.

The team hopes to eventually develop the simulation so that it runs interactively in real time, allowing trainee medics to administer treatments such as a tourniquet and see a realistic reaction immediately.

"We're genuinely hopeful that our simulations will enhance the educational experience for medical trainees," says Eldredge. "But I'm really pleased just to get visceral reactions from my kids. That probably makes me a horrible father."

The work was presented at the fluid-dynamics meeting of the American Physical Society last week and if you've got the stomach for it, you can watch the video at [bit.ly/NS\\_LegInjury](http://bit.ly/NS_LegInjury).



## Stone Age Picasso etched the oldest drawing of a settlement

OK, SO it's not quite a Picasso. But an etching on a slab of rock from the Late Stone Age that seems to show a group of seven huts may be the oldest ever depiction of human dwellings.

Carved roughly 13,800 years ago, the image appears to depict an everyday scene from a campsite, predating the oldest known images of human dwellings by 5000 to 6000 years.

"This shows for the first time the ability of prehistoric hunter-gatherers to represent society," says Marcos

García-Díez at the University of the Basque Country in Spain. With his colleague, Manuel Vaquero at the University of Rovira and Virgili in Tarragona, he discovered the engraving at Moli del Salt, an archaeological site 50 kilometres west of Barcelona.

They carried out detailed comparisons between the dimensions and shapes of the motifs and the huts made by present-day hunter-gatherers (*PLoS One*, DOI: 10.1371/journal.pone.0143002). "Our comparison

gives us a high degree of confidence that they are engraved huts," says García-Díez.

They think the etching was made by an individual who broke with the convention of abstract animal depictions that seems to dominate previously discovered ancient art.

But not everyone is convinced. Given that art from this period is often incomplete and quite abstract in nature, Paul Pettitt of Durham University, UK, wonders if the etchings may in fact represent highly stylised animals.

## Scotland's giant dinosaur footprints

NESSIE may be a mythical creature, but Scotland was once home to enormous dinosaurs that waded in shallow waters.

Stephen Brusatte from the University of Edinburgh, UK and his colleagues stumbled across several hundred footprints in a coastal lagoon on the Isle of Skye, which they dated to the Middle Jurassic, 170 million years ago (*Scottish Journal of Geology*, DOI: 10.1144/sjg.2015-005).

The size of the prints – up to 70 centimetres across – suggests they were left by early sauropods. "They had a bigger footprint than *T. rex*," says Brusatte. The largest creatures to ever have lived on land, these massive plant-eaters weighed around 20 tonnes, were up to 15 metres long and several storeys high.

This is the largest discovery of dinosaur footprints in Scotland, and it helps to piece together how and where these behemoths lived. "These dinosaurs weren't swimmers but they would have been moving around knee-deep in this brackish lagoon. Maybe the plants there were a good food source or maybe they got some protection from other dinosaurs there," says Brusatte.



CHRISTINA PAINTING

## Cage fights pry open evolution puzzle

**CHOOSE** your weapon... now fight! Harvestmen from New Zealand are the first animals found to have different types of weapon in a single species. Setting up fights between them could help to explain why the weird and wonderful world of animal weaponry got so diverse.

"We don't know what the benefits are to evolving different weapons," says Christina Painting at the University of Auckland. Since two species don't tend to interact, it's impossible to compare the costs and benefits of different weapons.

Now that could change, with her

discovery of a species with two weapons – and two different fighting tactics. *Pantopsalis cheliferoides* males can have either short, broader jaws, which they use like a dagger (pictured) or long, slender jaws they swing around like swords (*Scientific Reports*, doi.org/9kf). "It's just anecdotal evidence at this stage but I imagine they could clip each others' legs off," she says.

Males of the same species must naturally encounter one another, so will interact when introduced in the lab. "It's like watching evolution in action," she says.

**PHILIPS**

Living Health

# Home sweet home

Chronic illness can trap people in hospital. But what if they could access all the care they needed at home in virtual wards?

**IF YOU** have ever had to stay on a hospital ward, you will know how stressful it can be, no matter how caring and professional the medical staff. Besides the boredom and loneliness, there's the noise and lack of privacy.

Help is at hand, however, as a new type of hospital ward is beginning to open its doors. The difference is that in this ward, patients stay at home. The idea is to use the home as a "virtual" ward. Instead of staying in hospital longer than is strictly necessary, people go home to recover once they are out of danger.

But out of sight does not mean out of mind: medical teams still visit regularly – perhaps to re-dress wounds, give injections, provide physiotherapy or check blood pressure. And more high-tech virtual wards can use advanced telehealth devices, meaning people are issued with innovative wireless sensors that track their vital signs. These devices can continually feed data to cloud-based services, where predictive algorithms issue alerts if someone seems to be at risk of a serious health event, such as a heart attack. In this case, an emergency team can speed to the person's home to intervene.

Virtual wards allow people to monitor the parameters relevant to such conditions using

a variety of wireless vital-sign monitors that communicate with a tablet computer via Bluetooth. The sensors include blood pressure cuffs, blood glucose level meters, pulse oximeters that measure blood oxygen levels, heart rate monitors and even wireless weight and body fat scales.

## Information revolution

The tablet then connects to a cloud computing system, such as healthcare company Philips' HealthSuite Digital Platform, over the internet. This is where software keeps a check on the data, looking for dangerous trends and alerting doctors if any of the vital signs suggest trouble ahead. "There can also be an automated escalation that calls the right doctor for the condition at hand," says Alan Davies, Director of Home Healthcare at Philips, who runs the Hospital to Home service in the UK and Ireland.

The hospital side of the virtual ward operation has to be multidisciplinary – staffed by nurses, doctors, pharmacists, physiotherapists and nutritionists – so that the right decisions can be made about which people need to be visited by whom, and why they may need the intervention.

Although the sensors aren't novel in themselves, says Davies, the innovation is in the development of predictive algorithms for analysing and making sense of the data they collect. For example, these algorithms are now getting good enough, he says, to give a multidisciplinary team advance warning that people with heart failure may need a preventive intervention – well in advance of the need for an emergency readmission. Dealing with the problem early is often less invasive, perhaps involving medication, exercise or a nutritional change. "Imagine the high cost savings and benefits to the community in terms of freed-up bed capacity," Davies says.

John Huffman, Chief Technology Officer at Philips, is on the front line of the algorithmic innovation. An important point, he says, is that software can also aid in the decision to send someone home from hospital to their virtual ward. "It lets you see if it is safe to send someone home, working out the probability of them coming back and if they require healthcare support at home."

Another strategy to help people avoid ending up back in hospital can be to give them tools to take control of their conditions. "We provide disease educational material, often







**“Imagine the cost savings and benefits in terms of freed-up bed capacity”**

*Alan Davies, Dir Home Healthcare Philips*



Hospital care at home for those who need it most

in partnership with third sector charities, so patients can do more self-care at home. That way they can self-manage, stabilise themselves and thereby hopefully avoid more severe episodes,” says Davies.

Some virtual wards are already in operation and achieving encouraging results. In a landmark trial in 2013, Philips and Banner Health of Phoenix, Arizona, reduced hospital readmissions for a group of 135 chronically-ill patients by 45 per cent. Care costs during the trial also fell by 27 per cent.

Healthcare at Home of East Staffordshire is trialling such services in 21 UK National Health Service trusts. In 2014, it created 379 virtual beds – which it says is equivalent to building a new hospital. And the Nuffield Trust, a healthcare research and policy organisation based in London, has found that this approach began to reduce elective hospital admissions

**“The software works out if it is safe to send someone home and the chances of them coming back”**

*John Huffman, CTO Philips*

and outpatient attendances six months after the NHS trials began.

“Care on virtual wards is made possible through a range of technologies such as a digital patient record,” says a spokesperson for Healthcare at Home. “This enables healthcare professionals, using tablet computers, to access and update the patient’s clinical record and treatment pathway in near real-time.”

**Reduced readmissions**

Those who get to try virtual wards first will include people who cost health services the most. In the UK and the US, 50 per cent of healthcare spending is on just five per cent of patients: those with chronic diseases that have high hospital readmission rates. These conditions include chronic obstructive pulmonary disease, congestive heart failure, type-2 diabetes and high blood pressure.

“These are the conditions with the maximum impact on acute healthcare costs,” says Davies. Seeing as many people have a combination of these conditions, their frequent readmissions have a serious effect on bed capacity in hospitals, he says.

The virtual ward model lets healthcare providers assess risk for different groups

in the community – ensuring that the most at risk, chronically-ill people are also most likely to be given the help they need. This can focus telehealth efforts on those who are most likely to need expensive readmissions.

None of this will be easy, though. Allowing people to put the noise, stress and boredom of the old-style hospital ward behind them will need an enlightened attitude on the part of health authorities.

The reason? A good old turf war. With virtual wards in people’s homes, doctors’ surgeries will be effectively sharing community healthcare with hospitals – something they have never done and that some on both sides may oppose. But the NHS has vowed “to exploit the information revolution” as it strives to improve its services over the next five years, and virtual wards may well become part of that.

“So the problem about making virtual wards happen is not the technology,” says Davies. “There’s a cultural change here that has to be gone through.” ■

This story is part of a series exploring the way innovation is improving health. For more, visit: [newscientist.com/living\\_health](http://newscientist.com/living_health)

# A helping hand

Listening to the whispers our muscles make could be an easier way to control a prosthetic hand. **Sam Wong** gives it a go

PRESS your ear against your biceps, bend your arm and listen. The gurgling murmurs you can hear, made by muscle fibres as they move against each other, could provide a way for people to control prosthetic hands more easily.

In a lab at Imperial College London, PhD student Sam Wilson straps two matchbox-sized listening devices to my arm just below the elbow. I clench my hand and the robotic hand resting on the table makes a fist. I try using it to grab a soft cube. It escapes the hand's grip on my first few

attempts, but with a bit of practice it's easy.

Wilson and his supervisor Ravi Vaidyanathan are designing new ways for the human body to control prostheses. Typically, these use electrodes on the surface of the skin to pick up electrical activity in the arm muscles, called myoelectricity.

Vaidyanathan had the idea to develop different sensors for controlling prostheses when a colleague told him about a man who split his time between India and the UK, and claimed that his

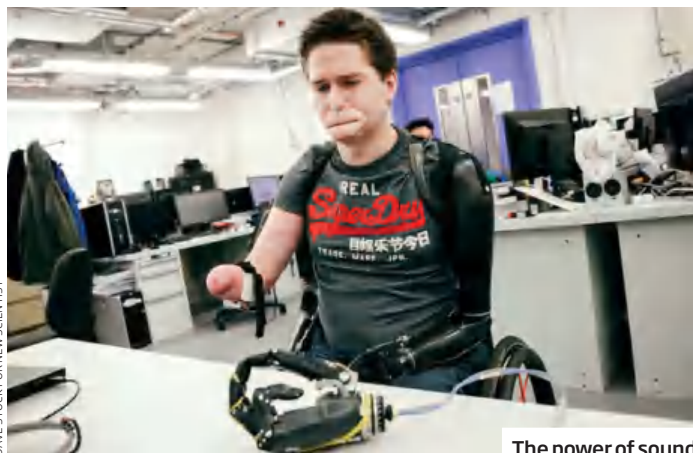
prosthetic hand knew when it was in India and stopped working. His doctors were baffled. Eventually they realised that the warmer Indian climate was the culprit: sweat was interfering with the electrodes that sense his muscle movements. It's a common problem with such prostheses: they don't work consistently for long periods.

**"It's incredibly easy to use. It's something I could probably use for 16 hours and not feel worn out"**

"We wondered if there was a more robust way of detecting muscle activity and harnessing it for robotic control," says Vaidyanathan.

He had been using accelerometers to sense muscle movements, but found that the gurgling muscle fibres were interfering with the signal. Using the sound input on its own is similarly noisy, but by combining inputs from a microphone and an accelerometer in one device, any unwanted signal can be reduced. "We can filter it out and make them feed off each other," he says.

Vaidyanathan and Wilson, whose PhD is sponsored by the US Office of Naval Research Global, are working with Alex Lewis to develop the technology. Lewis lost all of his limbs two years ago when a streptococcus infection developed into toxic shock,



The power of sound



Alex Lewis tests the system



septicaemia and necrotising fasciitis, also known as flesh-eating bacteria. He has a split hook prosthesis, where two metal hooks open and close based on electrical readings from his arm muscles, but finds it cumbersome to use.

"The weight is at the end of the socket, so it's very, very heavy," he says. "Trying to open and close the hook and rotate the wrist, it really works your muscle quite hard. It's an aggressive motion. You could only use it for maybe 3 or 4 hours at best."

Lewis is impressed with what Wilson has made. "It's incredibly easy to use. With the myoelectric split hook that I've got, I have to really force it to open and close. With this, it's a very, very slight movement. It's something I could probably use for 14, 16 hours and not feel worn out doing it."

Listening to our muscles' sounds makes it easier to get signals out of the body. But the devices those signals control are important, too. The hand Lewis and I are controlling is a Bebionic 2, manufactured by British firm RSL Steeper. Each digit has its own motor, and the user can choose between 14 grip patterns. While it looks impressive, inviting comparisons with Luke Skywalker's bionic hand in *Star Wars*, it isn't necessarily more useful than simple split hook prostheses, which have barely changed from a design patented in 1912.

## Price drop

"That hand is amazing, how it works, but the practicality of it is not that good," says Lewis. Choosing the desired grip pattern isn't trivial – the user has to press a button on the back of the hand to cycle through the options – and it's quite heavy. "I think long-term use is out of the question because of the weight," he says. At a cost of around £30,000, advanced bionic hands like Bebionic and the Deka Arm System are also prohibitively expensive for most people.

Vaidyanathan hopes his

research will help make these devices more accessible. The sensor package they are working with costs less than £100.

"I think the technology has been developing at such a rate that people haven't focused on the price as much yet," he says. "That's one of the niches I hope this interface can help with." Lewis has a trust to raise money for prostheses and other rehabilitation costs.

Vaidyanathan's team has already made the hand a bit simpler for Lewis to use by rigging the sensors to allow him to switch grips with an exaggerated upward movement of his arm. Another of his students is working on using a camera under the hand's wrist to detect objects and automatically choose the most suitable grip.

Lewis is an interior designer, and one of his biggest daily challenges is holding a stylus to work on a computer for hours at a time. Rather than his heavy myoelectric prosthesis, he mainly uses body-powered split hooks, which rely on cables to transmit force from his shoulders to close the grip. They are easier to use, but put a lot of strain on his shoulders over time.

Nor would the Bebionic 2 help. "Although the hand's nice to look at, I probably would only use a thumb, index finger and middle finger," says Lewis. Vaidyanathan is planning to design a modified split hook prosthesis with a small motor controlled by their new sensor interface, to help Lewis hold a stylus more easily.

They are also thinking about what other functions around the house it would be useful to control with the sensor, like light switches or the TV. It's less glamorous than developing bionic hands that can be controlled effortlessly, but more likely to be of use for people.

"Engineers like to build things, but they have to be going in the right direction," says Vaidyanathan. "Otherwise we just end up with toys." ■



# Computer's imagination creates human faces

EVER wondered what computers think we look like? An artificial neural network has been trained to conjure realistic-looking images on demand, including human faces.

Artificial neural networks are used to pick out specific characteristics from large datasets, such as simple geometric shapes, or more complex figures like cats or faces. They learn by analysing training data like photos, but exactly how different components of a network learn to recognise particular objects is rather opaque. Google's psychedelic DeepDream landscapes are a recent example: in these, the computer "sees" dogs, birds and other objects that aren't really there.

Now, Alec Radford of machine learning firm Indico in Boston and Facebook's AI research lab in New York have looked at a particular type of network called a generative adversarial network. In these, one part of the system tries to invent fake data to fool another part into mistaking it for training data. The idea is that by repeatedly pitting the network against itself, it will learn to produce better results.

In one experiment, the team trained the network on pictures of faces and then tried out a kind of visual arithmetic. They gave the network pictures of smiling women,

then told it to "subtract" pictures of women with neutral expressions and "add" men with neutral expressions. The goal was to extract the concept of "smiling" and combine it with the concept of "man". The results were entirely imagined pictures of smiling men ([arxiv.org/abs/1511.06434](http://arxiv.org/abs/1511.06434).)

The team also trained the system on a database of photos of bedrooms, then asked it to produce its own images. To prove it wasn't just copying the original data, they asked the network to generate a series of

**"The neural network extracted the concept of 'smiling' to create entirely imagined pictures"**

related pictures of the same scene, such as a bedroom with or without a window, or one in which a TV morphs into a window. This shows that the network is able to figure out how certain features fit into a scene, they say, and allowed them to identify which parts of the network were learning which objects.

For now the images are limited to just 32 by 32 pixels, but scaling up could lead to a kind of Google image search for pictures that don't actually exist – you'd simply write a description and the computer would generate the image for you. Jacob Aron ■

## INSIGHT Personal flight

# Have jetpack, will travel

It feels like the dream could be getting closer, says **Hal Hodson**

IN EARLY November, Australian inventor David Mayman took off from the deck of a barge floating in New York Harbour. He rose into the air, circled the Statue of Liberty, then alighted gently back on the boat. He made the trip using two turbines joined to a kerosene-filled backpack – a jetpack, in other words.

One week after his flight, Dubai's firefighting service signed an agreement to buy 20 jetpacks from a New Zealand company called Martin Jetpack. The month before, two men in winged jetpacks had taken to the skies above Dubai, flying in formation next to the world's biggest airliner, the Airbus A380. Are real, functional jetpacks finally arriving for all of us?

Well, not quite. Whether or not a backpack can lift a person into the sky depends on a few fundamentals: being small enough to wear, having fuel that contains enough energy for

the flight time to be useful, and being sufficiently reliable so as not to fall out of the sky. Stunt jetpacks seem to meet those goals, but there are huge barriers to wider adoption.

Safety is the biggest hurdle. It takes an experienced pilot to keep themselves upright, balanced and flying on two streams of hot gas. Even

**"The Martin Jetpack has tonnes of control algorithms, or you wouldn't be able to fly it"**

the propeller-based Martin Jetpacks require two weeks of training. Gareth Padfield of the University of Liverpool, UK, says automation has a role to play in enabling the average person to pilot a craft that would be inherently unstable without the constant monitoring of an autonomous nanny.

"The Martin Jetpack has got tonnes

of control algorithms. If they didn't have this there would be no chance they'd be able to fly it," says mechanical engineer Mathieu Sellier of the University of Canterbury in New Zealand, who has worked on previous models of the Martin Jetpack. "It's always on the verge of instability. You need to correct trajectory many, many times per second."

A jetpack for the masses will also need to be environmentally friendly, says Padfield. "If we've got a constant hum of these vehicles they're not going to be acceptable. If they are strong emitters of pollution they're not going to be acceptable."

His group, along with a consortium of European research institutions, is considering small electric helicopters instead of jet turbines, helping to skirt the environmental issues.

One final barrier is the basic limitations of our fuels – it's hard to find one with a high enough ratio of energy to mass to lift a person off the ground while they are wearing the tank that holds the fuel. Stunt jetpacks may already be pushing the limits of what's possible.

"Lifting a man with a device that you put on your back is probably not far off the limit, short of using nuclear power," says Sellier. Jetpacks might find a use in search and rescue in inaccessible places, but wouldn't be able to carry anyone out.

The answer may be personal air vehicles that transform as soon as they get off the ground – jets or propellers for take-off, with wings for travel that provide lift and efficiency. Padfield's group is looking for ways to integrate wings and helicopter blades to retain the benefits of both systems.

Even so Mayman's Statue of Liberty moment feels like the start of a new chapter. "This definitely looked more like sci-fi," says Sellier. ■

## ONE PER CENT



## The \$5 computer

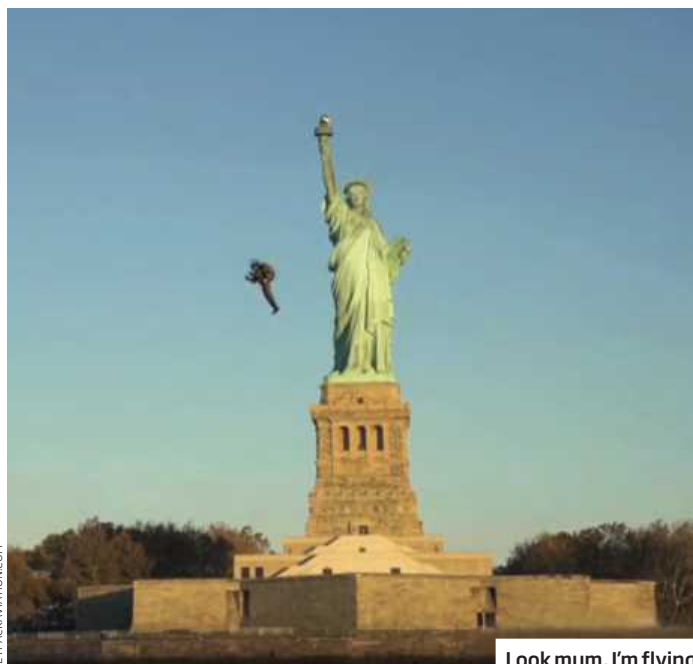
The future has arrived. You can now buy a computer for the price of a sandwich, after the release of the Raspberry Pi Zero last week. The latest version of the bare-bones computer costs just \$5, or £4 in the UK. It can plug into a monitor and keyboard to function as a normal computer, or run dedicated software to do things like block adverts throughout a home Wi-Fi network.

**"One day, seeing Prime Air vehicles will be as normal as seeing mail trucks on the road"**

Last weekend, Amazon announced that it is testing a drone delivery service in the US, UK and Israel

## Nodding along

**What are you working on?**  
A wearable device developed at the University of New South Wales, Australia, aims to follow what you are doing – and how hard you are working – by tracking your head movement. The device straps to a baseball cap and tracks the wearer's motion. When tested on 20 university students working on mathematics problems, it was 80 per cent accurate at telling how difficult the problems were.



Look mum, I'm flying



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## Ready for lift-off

BUCKLE up. The LISA Pathfinder spacecraft prepares to be enclosed within two half-shells of a Vega rocket fairing at the Guiana Space Centre in French Guiana, 16 days before launch.

Due to blast off on 2 December at 0415 GMT, the rocket will carry LISA Pathfinder on the first leg of its journey into a low Earth orbit. I will be there to watch the launch and report back on it.

If all goes to plan, the fairing will then be jettisoned and the spacecraft will use its own propulsion module to manoeuvre itself into its operational orbit at the first Lagrange point, L1. This is where gravitational forces balance to keep the craft in a stable position between Earth and the sun.

LISA Pathfinder is to carry instruments designed to detect gravitational waves - ripples in space-time predicted by Einstein's theory of general relativity. If Einstein was right, gravitational waves emanate from supermassive black holes as they pull in other objects, but they have never been observed directly.

Once in position, two gold-platinum cubes will be released in perfect free fall inside the spacecraft, isolated from non-gravitational forces such as sunlight, and their positions tracked with lasers. It's a crucial test of the technology that the European Space Agency hopes to deploy in the eLISA mission, set for 2034, which aims to let us see hidden parts of the universe by monitoring gravitational waves. Sam Wong

## Photograph

Manuel Pedoussaut/ESA

# Climate's conflict zone

Observers such as Prince Charles talk up climate change as a factor in Syria's war, but the claims are under fire, finds **Fred Pearce**

IT HAS been repeatedly claimed that refugees fleeing Syria are victims of climate change as well as victims of a vicious civil, and now international, conflagration.

*Scientific American* declared that global warming "hastened" the war, and US president Barack Obama said "drought and crop failures and high food prices helped fuel the early unrest". The latest intervention comes from UK royal Prince Charles, who echoed those views in a TV interview broadcast last week.

But critics say the link between climate and conflict is not sound, and some social scientists warn that implicating global warming in this way may take the heat off unsavoury regimes, such as that of Syria's president, Bashar al-Assad.

The idea that the Syrian conflict is a climate war has been around since 2012. But it really made headlines in March this year with a paper by Colin Kelley of the University of California, Santa Barbara, and his colleagues (*PNAS*, doi.org/10/2/jw).

The researchers argued that a drought between 2006 and 2009 in north-eastern Syria, the country's breadbasket, was the worst recorded in the region and had been made more likely by long-term, probably human-induced climate change.

So far, so uncontroversial. But Kelley then noted how, after their crops and livestock were lost, many farmers and their families moved to cities where rebellions against Assad later took place. While he didn't go as far as saying the drought caused the war, he concluded that "human



influences on the climate system are implicated in the current Syrian conflict".

That last part of the narrative is particularly disputed. Was the drought itself the true trigger of internal migration? How big was the flight of people? And did the movements drive the unrest that preceded war?

There is a nuanced debate about the first question, the extent to which failed rains triggered the migrations. Most analysts, including Kelley, agree that there were compounding factors, such as ill-conceived government irrigation schemes that left water reserves dangerously low even before the drought. But Kelley

says the drought, and by inference human-induced climate change, was a significant factor.

On the second question, the size of the pre-war migration is more openly contested. Kelley said it involved "as many as 1.5 million people". That figure rests on a media quote from a Syrian minister. Some other estimates, which Kelley lists but does not quote from, are far lower. In 2010, after the drought was over, the UN and the International Center for Agricultural Research

in the Dry Areas, which is based in the heart of the drought and conflict zone in Aleppo, settled on a figure of around 300,000 people. Kelley said the higher figure came from "anecdotal but not citable sources" but was "more realistic".

Finally, to the third question: whether these migrants, by swelling slums in Syrian cities, caused the unrest that triggered the civil war. Here, as well as a quote from a migrant in *The New York Times*, Kelley cited a news dispatch from the UN High Commissioner for Refugees. That turned out to be about some of the 1 million Iraqi refugees fleeing sectarian violence who arrived in the same region before the drought. It says nothing at all about drought refugees or internal Syrian migrants.

When I pointed this out, Kelley said this reference was probably incorrect, and suggested another, which said, among other things, that "it was not the drought per se, but rather the government's failure to respond to the ensuing humanitarian crisis that formed one of the triggers of the uprising". This take might explain why the first signs of conflict did not emerge until 2011, almost two years after the drought ended.

Sociologists critical of the Syrian climate-war argument have a problem with climate scientists linking natural events, such as a drought, and political consequences, including war.

One of them is Betsy Hartmann of Hampshire College in Amherst, Massachusetts, who says the climate-war narrative repeats the one used for the bloody conflict in

**"Climate explanations may let real perpetrators of war off the hook by suggesting they are mere bit players"**



Darfur in Sudan a decade ago, which saw government-backed tribal militias killing people in pastoral communities.

In 2007, the UN Environment Programme endorsed a widely held view that the root cause was drought and desertification, and that “Sudan is unlikely to see a lasting peace unless widespread and rapidly accelerating environmental degradation is urgently addressed”. And yet the Intergovernmental Panel on Climate Change later concluded that most studies of the Darfur conflict said that “government practices [were] far more influential drivers than climate variability”. But, says Hartmann, “the story just moved on to Syria”.

Apart from complaining about natural scientists dabbling in social sciences, her beef is that such explanations are open to the accusation that they let the real perpetrators off the hook by suggesting that Sudanese ministers or Assad in Syria are mere bit-part players in a wider climatic disaster, rather than the principal instigators.

Of course, climate researchers have every right to examine possible links between droughts, migrations and conflicts. Their concern is understandable, given the ferocity and duration of the war and its growing impact beyond the region with the rise of ISIS and the refugee crisis in the Middle East and Europe.

However, it is just as fair for sociologists to question the jump from natural science to ideas of causality in the highly complex human sphere.

We hear much talk about the need to adapt to unavoidable climate change. One thing both sides would probably agree on is that a lot of the ability to adapt will come from ensuring stable, flexible and fair societies in countries on the front line. All things Syria turned out not to be. ■

Fred Pearce is a consultant for *New Scientist*

## ONE MINUTE INTERVIEW

# Doomed glacial hotspots

I'm climbing to the world's vanishing equatorial glaciers to highlight the dangers of climate change, says **Tim Jarvis**



### PROFILE

Tim Jarvis is an environmental scientist and explorer. He recently re-enacted Shackleton's 1914-16 journey to South Georgia. His current campaign, TwentyFiveZero, highlights the impact of climate change on the world's glaciers.

**I'm talking to you as you descend from the summit of the Carstensz Pyramid in Indonesia. How was the climb?**

It was extreme, very steep. One wrong foot and you're falling a long way. We started at 1am this morning and reached the summit at dawn. It is unbelievably spectacular: you're looking down on forest canopy with mountains poking through the clouds and the last remaining glaciers on the flanks of the mountains.

**This climb is part of your TwentyFiveZero campaign. What is this about?**

There are 25 mountains on the equator that still have glaciers. The glaciers have been here since the last ice age, but within a quarter of a century they will all be gone because of human-induced climate change. The ones here in Indonesia have about five years left. Over the two weeks of the UN climate conference in Paris, we're climbing three of these mountains: Carstensz in Indonesia, Mount Stanley in Uganda and Chimborazo in Ecuador. I'll be climbing all 25

of these mountains over the next two years.

One of the aims is to try to influence the talks in Paris by broadcasting our climbs directly to them. A sense of urgency is key. The problem with climate change is that it's not tangible, it's invisible. You need to find proxies for it, and melting glaciers are a good visual indicator of what's happening.

**How big are the effects of climate change that you have seen on your expeditions?**

The effects are very clear. Arctic sea ice has reduced by about half. It is very apparent in the Antarctic too. Shackleton had to cross three glaciers when he got to South Georgia on his 1914-16 journey. When we retraced his footsteps in 2013, we only had to cross two glaciers because the third one was a lake. I knew then that melting glaciers would make people sit up and take notice of what was going on.

**Are there other things that you learned while retracing Shackleton's journey that are proving useful in the TwentyFiveZero campaign?**

Yes. Firstly, the powerful visual images you bring back from these places are a good way of influencing opinion. Secondly, Shackleton's leadership was all about getting a disparate group of people to follow in the same direction to achieve a single goal, in their case their own survival. I feel those same leadership skills could be brought to bear in bringing together all the stakeholders in the fight against climate change.

**How do you think the world is doing in the fight against climate change?**

All the governments attending the Paris conference submitted plans in advance for what they're prepared to do in terms of carbon reduction, and those plans together don't add up to keeping us at 2 °C of warming, which isn't good. On the other hand, this does represent progress as everybody submitted a plan, including developing countries who weren't obligated to act under the previous Kyoto Protocol.

**Interview by Michael Bond**

# A bit in owttwo minds

Could quantum fuzziness be behind the peculiar computing abilities of the human brain, asks Michael Brooks

**M**ATTHEW FISHER was wary of how his peers would react to his latest project. In the end he was relieved he wasn't laughed out of court. "They told me that this is sensible science – I'm not crazy."

Certainly nothing in Fisher's CV says crazy. A specialist in the quantum properties of materials, he worked at IBM and then at Microsoft's Research Station Q developing quantum computers. He is now a professor at the Kavli Institute for Theoretical Physics at the University of California Santa Barbara. This year he won a share of the American Physical Society's Oliver E. Buckley prize in condensed matter physics, many recipients of which have gone on to win a Nobel.

The thing was, he had broached a subject many physicists would rather simply avoid.

"Does the brain use quantum mechanics? That's a perfectly legitimate question," says Fisher. On one level, he is right – and the answer is yes. The brain is composed of atoms, and atoms follow the laws of quantum physics. But Fisher is really asking whether the strange properties of quantum objects – being in two places at once, seeming to instantly influence each other over distance and so on – could explain still-perplexing aspects of human cognition. And that, it turns out, is a very contentious question indeed.

The most basic objection comes from Occam's razor, the principle that says the simplest explanation is usually the best. In this view, current non-quantum ideas of

the brain's workings are doing just fine. "The evidence is building up that we can explain everything interesting about the mind in terms of interactions of neurons," says philosopher Paul Thagard of the University of Waterloo in Ontario, Canada. Physicist David Deutsch of the University of Oxford agrees. "Is there any need to invoke quantum physics to explain cognition?" he asks. "I don't know of one, and I'd be amazed if one emerges."

Fisher is less sure, pointing out that current ideas about memories are far from watertight – for example, that they are stored in the architecture of neuron networks or in the junctions between neurons. "My gut instinct is that neuroscience has lots of things that remain puzzling," says Fisher. So why not see if there are better quantum explanations?

Perhaps because we've been here before. In 1989, Oxford mathematician Roger Penrose proposed that no standard, classical model of computing would ever explain how the brain produces thought and conscious experience. The suggestion intrigued a lot of people, not least an Arizona-based anaesthetist called Stuart Hameroff, who suggested a specific way for quantum effects to get involved.

The crux of the idea was that microtubules – protein tubes that make up neurons' support structure – exploit quantum effects to exist in "superpositions" of two different shapes at once. Each of these shapes amounts to a bit of classical information, so this shape-shifting ➤





quantum bit, or qubit, can store twice as much information as its classical counterpart.

Add entanglement to the mix – a quantum feature that allows qubit states to remain intertwined even when not in contact – and you rapidly build a quantum computer that can manipulate and store information far more efficiently than any classical computer. In fact, Penrose suggested, the way such a computer can arrive at many answers simultaneously, and combine those answers in different ways, would be just the thing to explain the brain's peculiar genius.

Penrose and Hameroff collaborated on the idea, and they and others kicked it around as a sensible proposal for a while. But holes soon began to appear.

From a physicist's perspective, the most fundamental problem was coherence time. Superposition and entanglement are both extremely fragile phenomena. Think of a human pyramid of performers crossing a high wire on a unicycle and you get the idea. The slightest disturbance and their grip slips. In the case of a quantum system, it will “decohere” to a bog-standard classical state if disturbed by heat, a mechanical vibration or anything else. The information stored in the quantum states is generally lost to the surrounding environment.

This problem has hampered attempts over the past two decades by physicists, Fisher included, to engineer a quantum computer of any significant size. Even in cryogenically cooled and mechanically isolated conditions, it's a struggle to keep qubit networks coherent for long enough to do anything

beyond the capabilities of classical computers.

In the warm, wet brain, with its soup of jiggling, jostling molecules, it becomes almost impossible. Neurons hold information for microseconds at a time or more while processing it, but calculations suggest that the microtubule superpositions would last only between  $10^{-20}$  and  $10^{-13}$  seconds. Neurophilosopher Patricia Churchland summed up what came to be the mainstream view: “Pixie dust in the synapses is about as explanatorily powerful as quantum coherence in the microtubules,” she wrote in 1996.

## “Maintaining quantum effects in the warm, wet brain should be impossible”

Fisher shared that scepticism. “When they started talking about microtubules, I knew immediately it didn't make sense,” he says. “It's impossible to work with quantum information unless you can control it and keep it from entangling with the environment.”

But equally, he thought, wouldn't it be odd if evolution hadn't worked that out? Life has had billions of years to “discover” quantum mechanics, and its exquisite molecular apparatus gives it the means to exploit it. Even if electrical impulses among neurons within the brain – something well described by classical physics – are the immediate basis of thought and memory, a hidden quantum layer might determine, in part, how those neurons correlate and fire.

Fisher's personal interest in the subject began in a rather roundabout way, while wondering about the persistence of mental illness among people close to him, as well as the efficacy of the drugs used to treat them. “No one truly knows how any of the psychiatric pharmaceuticals work,” he says. There's a reason for that. It would require a much better understanding of what the drugs are trying to modify: the human mind.

The initial focus of Fisher's interest was lithium, an ingredient of many mood stabilising drugs. As he combed the scientific literature, he happened across one particular report from 1986 that gave him pause for thought. It described an experiment in which rats were fed one of the two stable isotopes of lithium: lithium-6 and lithium-7. When it came to grooming, nursing of pups, nest-building, feeding and several other measures, those fed lithium-6 were enormously more active than control groups or those fed lithium-7 (*Biological Psychiatry*, vol 21, p 1258).

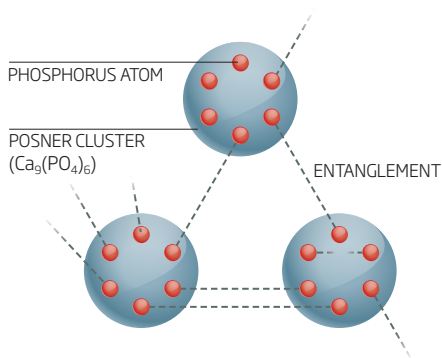
It was this paper that led Fisher to think it might be time to open the whole quantum cognition can of worms once again. All atomic nuclei, like the fundamental particles that make them up, have a quantum-mechanical property called spin. Crudely, spin quantifies how much a nucleus “feels” electric and magnetic fields; the higher the spin, the greater the interaction. A nucleus with the very lowest possible spin value,  $1/2$ , feels virtually no interaction with electric fields and only a very small magnetic interaction. So in an environment such as the brain, where electric fields abound, nuclei with a spin of  $1/2$  would be peculiarly isolated from disturbance.

Spin- $1/2$  nuclei are not common in nature, but here's the thing. The spin value of lithium-6 is 1, but in the sort of chemical environment found in the brain, a water-based salt solution, the presence of the water's extra protons is known to make it act like a spin- $1/2$  nucleus. Experiments as long ago as the 1970s had noted that lithium-6 nuclei could hold their spin steady for as long as 5 minutes. If there is an element of quantum control to the brain's computation, Fisher reasoned, lithium's calming effects might be down to the incorporation of these peculiarly coherent nuclei into the brain's chemistry.

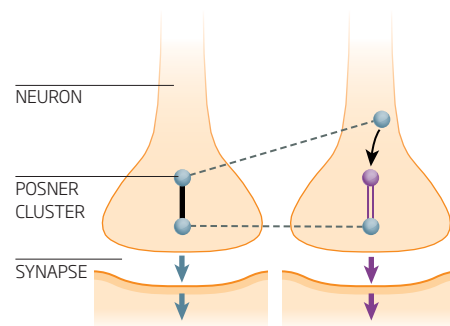
And not just that. Lithium-6 does not occur naturally in the brain, but one nucleus with a spin- $1/2$  does, and it is an active participant in many biochemical reactions: phosphorus. The seed in Fisher's mind was beginning to sprout. “If quantum processing is going on in the brain, phosphorus's nuclear spin is

## Joined-up thinking

Posner clusters thought to be found in the brain contain six phosphorus atoms whose nuclear spin states can be quantum entangled – perhaps influencing how we think and remember



Change the spin state of one entangled phosphorus atom and the state of its entangled partner changes too – regardless how far apart they are



Entangled Posner clusters involved in chemical signalling in one brain neuron could induce similar reactions in another neuron

the only way it could occur,” Fisher says.

After exhaustive calculations of the coherence times of various phosphorus-based molecules in biological settings, Fisher has now gone public with a candidate qubit. It is a calcium phosphate structure known as a Posner molecule or cluster. It was identified in bone mineral in 1975 and has also been seen floating around when simulated body fluids – that is, water with added biological molecules and mineral salts – are concocted in the lab. When Fisher estimated the coherence time for these molecules, it came out as a whopping  $10^5$  seconds – a whole day.

He has also identified at least one chemical reaction in the brain that he thinks would naturally manufacture entangled, coherent states between nuclear spins within Posner molecules. It is a process involved in calcium absorption and fat metabolism that uses an enzyme called pyrophosphatase. This enzyme breaks down structures made of two interlinked phosphate ions, producing two single ions. Theoretically, at least, the nuclear spins in these two ions should be quantum entangled. Release them into the fluid surrounding the cells, and they can combine with calcium ions to form Posner molecules.

If this is all correct, the brain’s extracellular fluid could be awash with complex clusters of highly entangled Posner molecules. Once inside the neurons, these molecules could begin to alter the way the cells signal and respond, starting to form thoughts and memories (see diagram, left).

Fisher published the details of his proposal in *Annals of Physics* last month (vol 362, p 593). Much of it, he admits, is highly speculative. “I’m still at the stage of telling stories,” he says. “I have to get some experiments done.”

## The c-word

The first test will be whether Posner molecules exist in real extracellular fluids. If they do, can they be entangled? Fisher envisages testing this in the lab by inducing the chemical reactions suspected to entangle phosphorus nuclear spins, pouring the resulting solution into two test tubes and looking for quantum correlations between light given out from the two. Observe such correlations, and you might just begin to make a case for quantum cognition. “That test can be done, and I’ll make sure it is done,” says Fisher.

Penrose is – perhaps predictably – excited by the story so far. “Stuart Hameroff and I have been of the opinion that nuclear spins might be an important ingredient of



long-term memory for quite a while,” he says. “Matthew Fisher’s idea could well provide a very positive contribution to this picture.”

Penrose still pins his colours to his microtubule hypothesis, however, seeing the new proposal as a mere add-on that allows for lasting memory. “The phenomenon of consciousness is much more likely to be connected with the quantum actions of

**“The idea that the brain is too messy for quantum effects is simple-minded”**

interconnected microtubules,” he says.

For Penrose, consciousness has to do with gravity acting on quantum states and thus causing them to decohere; microtubules are more massive than nuclei, and thus more likely to be the cause of this interaction, he says. Fisher would rather not go down this road, and says he has studiously avoided any mention of the c-word – consciousness – in his paper, concentrating instead on better-defined concepts such as memory.

His proposal might not be crazy, but does it do enough to convince sceptics to look again for quantum effects in the brain? Thagard declares himself open-minded. He points to evidence that has accumulated in the past quarter-century showing that other biological processes, such as photosynthesis, involve long-lived coherent quantum states. Vlatko Vedral of the University of Oxford also sees some value in Fisher’s work. The idea that a warm, wet brain is too messy to have useful coherences is “simple-minded,” he says.

## Quantum control of the brain is controversial

Beyond that, he is not sure what exact part Fisher’s mechanism might play. “But at least he has suggested experiments that might be able to probe this issue further,” he says.

If there is any hint of success, Fisher has plenty of ideas lined up to test. There’s the lithium question, and also whether related spin effects might explain mercury’s influence on the brain – the phenomenon that became known as mad hatter disease, because hat-making traditionally involved prolonged exposure to mercury. Some commonly abundant isotopes of mercury have non-zero nuclear spin and might decohere phosphorus nuclear spins if caught inside a Posner molecule.

The questions keep coming. Does a bang on the head induce memory loss because it causes decoherence? Is nuclear spin the reason you can change brain states with transcranial magnetic stimulation, which fires a magnetic field across the brain? Fisher is working with neuroscientists and molecular biologists at Stanford University in California, where he is now on sabbatical, to address such questions. Most have taken a lot of convincing, he admits.

Johnjoe McFadden, a molecular biologist at the University of Surrey in Guildford, UK, is one researcher who remains to be persuaded. He once again invokes Occam’s razor. “There are too many bits of it that need to hold together to make a coherent story,” he says. “If any one aspect goes missing, it all falls apart.”

Thagard, too, is waiting for the fall. “Do you need that extra level of explanation to account for interesting psychological phenomena? I don’t think so,” he says. But that’s no reason not to seriously evaluate such proposals, he adds. “One of the great strengths of science is that people try different approaches and you get competing explanations. That’s all good. I’m just putting my money on a different one.”

Fisher meanwhile is putting his money where his mouth is: he has spent \$20,000 of his own cash filing a patent on treating depression and similar mental conditions with compounds enriched in lithium-6. Perhaps appropriately, though, he remains in two minds about whether it will lead anywhere. “Could quantum cognition make sense of these things that are missing from our understanding of neuroscience?” he asks reflexively. “Maybe, yes.” ■

Michael Brooks is a consultant for *New Scientist*



# the LIFE EDITOR

Biology is undergoing a revolution. Michael le Page reports on the gene-editing technique that is changing everything

**T**HE food on your plate. The pets at your feet. The plants in your garden. The mosquitoes whining in your ear at night. The cells in your body. And perhaps even the brains and bodies of your children. All of these could be transformed by a new gene-editing technique – starting in your lifetime.

Terms like breakthrough and revolutionary are much abused. But when it comes to CRISPR gene editing, they are probably understatements. “The technology is unbelievable,” says Kamel Khalili of Temple University in Philadelphia, who thinks it could clear viruses like HIV from the body.

## Major impact

The pace of innovation is breathtaking. Just a few years after its invention, CRISPR gene editing is already having a major impact on biomedical research. It makes it easy to “turn off” genes one at a time, to see what they do. It can introduce specific mutations, to find out why they make cells cancerous or predispose people to diseases. And it can be used to tinker with the genes of plants and animals, to create

drought-resistant maize, more muscular police dogs and much more.

In the not too distant future, CRISPR-based research could bring drugs for tackling obesity, more powerful gene therapies and plentiful supplies of transplant organs. “CRISPR is evolving incredibly fast,” says Waseem Qasim of University College London, whose team recently used an older form of gene editing to save the life of a baby with leukaemia. “We can’t keep up.”

Then there is the most controversial application: it could be used to permanently alter the genomes of our descendants, in order to eradicate disease-causing mutations or even to enhance children by adding beneficial gene variants that both their parents lack.

We have been talking about the possibility of genetically engineering humans for decades, says Debra Mathews of the Johns Hopkins Berman Institute of Bioethics in Baltimore. “But we’ve never had a technology that had a reasonable chance of doing what we want to do without causing harm before.”

This so-called germline gene editing hit the headlines in April, when the results of the first attempts to modify human embryos with CRISPR were published by a team in China. Rumours about such attempts had already led to calls for a voluntary ban on editing genes in human embryos. That’s one of the issues on the agenda at an international meeting on gene editing hosted by the US National Academy of Sciences this week.

Those in favour of such research say there might be good reasons for allowing germline gene editing, and that it is a powerful tool for understanding human embryonic development, which may reveal why some people are infertile or miscarry, for example.

In the following pages we look at the potential of CRISPR gene editing to transform medicine – and also its dangers.

## GENE EDITING DECODED

**GERMLINE EDITING** Altering the genes of sperm and egg cells, or early embryos, so that changes are passed to subsequent generations

**SOMATIC CELLS** All cells in the body except sperm and eggs. Changes to these cells are not passed on to offspring

**CRISPR** Gene-editing technique derived from a mechanism that bacteria use to fight off viruses. Cheaper, faster and more precise than earlier methods

**GENE DRIVE** Gene-editing technique that allows traits to spread faster through a population than they would normally

**PGD (preimplantation genetic diagnosis)** Screening embryos fertilised through IVF for genetic diseases before they are implanted in a woman’s uterus



## *Will this lead to* **DESIGNER BABIES?**

**G**enetically modified superhumans. Babies born with made-to-order characteristics. The idea has been explored in everything from academic journals to movies. CRISPR technology could make it a reality.

The ability to alter human genes in a way that can be passed onto offspring, called germline engineering, has long been possible. But until recently the methods available to genetically modify animals were so inefficient and crude that no sane biologist would dream of using them on humans. Tinkering with the genes inside people has been limited to gene therapy, where the changes don't get passed to the next generation (see "Will gene therapy go mainstream", overleaf).

Now the precision and efficiency of CRISPR has reopened the debate about human germline engineering. But why do it? The most compelling reason would be to prevent the inheritance of genetic diseases, yet this is already being done without gene editing.

### **Dialling out disease**

One approach is prenatal testing, which involves screening for the disease-causing mutation during pregnancy, giving parents the option of abortion. Another is preimplantation genetic diagnosis (PGD), in which prospective parents who undergo IVF have their embryos screened. Only those that won't develop the disease in question are then implanted. PGD can already be used to prevent thousands of serious genetic diseases.

But PGD is impractical if a child is at risk of inheriting two or more disorders. For two disorders, three-quarters of embryos might be unsuitable – and with couples getting only a handful of embryos per IVF cycle, rejecting three-quarters of them would make conceiving far less likely.

In fact, even with single disorders some couples get so few embryos ➤

PAUL RYDING





STEPHEN ISSEY/GETTY

that none of them would be free of the disease-causing mutation. In these instances gene editing could be used to fix their DNA – an option some regard as ethically preferable to discarding embryos, says Robin Lovell-Badge of the Francis Crick Institute in London.

Similarly, while PGD is impractical for getting rid of the harmful gene variants that increase the risk of common conditions, such as heart disease, diabetes, Alzheimer's or schizophrenia, it might be feasible with gene editing. Eliminating dozens of these harmful variants

*"Even if gene editing were safe, we are a long way from being able to engineer intelligence"*

could make a huge difference, allowing people to live longer, healthier and even happier lives.

This has huge potential for reducing the disease burden, says Chris Gyngell, who studies the ethics of human enhancement at the University of Oxford.

But the technology isn't there just yet. Nor do we know enough about

the gene variants involved to start eradicating them. All this means that when it comes to reducing the risk of diseases, there is currently no compelling reason to attempt germline gene editing.

What about the far more controversial idea of enhancing children, by giving them gene variants both their parents lack? Many of the variants controlling skin, hair and eye colour have been identified, so in theory these kinds of cosmetic traits could be tweaked. But characteristics such as intelligence seem to be determined by hundreds of different gene variants, with each one having only a tiny effect. This means we are a long way from engineering intelligence into children, even if gene editing were safe enough to attempt it.

And that isn't yet clear. The most serious issue is that gene-edited embryos are often a mix of cells with the desired genetic change and cells without it – a phenomenon called mosaicism. The Chinese team observed this in their first attempt to edit human embryos.

Everyone in the field agrees it is far too soon to attempt to alter children. A few have gone much further and ➤

## HOW DOES IT WORK?

The first forms of genetic engineering involved adding extra bits of DNA to the genomes of plants and animals, with no control over where they ended up. One method involved shooting bullets coated with DNA at cells.

Gene editing, in contrast, adds DNA to precise spots in a genome, or alters a specific sequence, so is far superior. While a few methods of gene editing had been developed, until the advent of CRISPR, it was usually slow, difficult and very expensive.

CRISPR targets a particular DNA sequence using a piece of RNA that's complementary to that DNA. Linked to it is a protein derived from bacteria, called Cas9. The RNA finds the right bit of DNA and binds to it, then Cas9 cuts it (see diagram, right). The cell's repair mechanisms will re-join the two pieces, but in the process the DNA sequence gets slightly altered. This is how genes can be disabled.

## Donor DNA

If, however, donor DNA with ends that match the DNA on either side of the cut segment is added to cells too, the cell thinks it is a fragment of broken DNA and will splice it into the genome exactly where the cut was made – adding DNA to a precise spot.

The Cas9 protein can also be modified so that instead of cutting DNA, it controls the activity of the local gene or genes – boosting or blocking their activity.

The effects of this will be short-lived: things return to normal once the Cas9 protein breaks down.

But it may be possible to produce longer-term changes in gene expression through epigenome editing, which alters gene switches, rather than genes themselves. This could one day help treat the wide range of disorders thought to involve epigenetic changes, including addiction and depression.



It could be possible  
to target HIV hiding  
inside immune cells

## Cut and paste

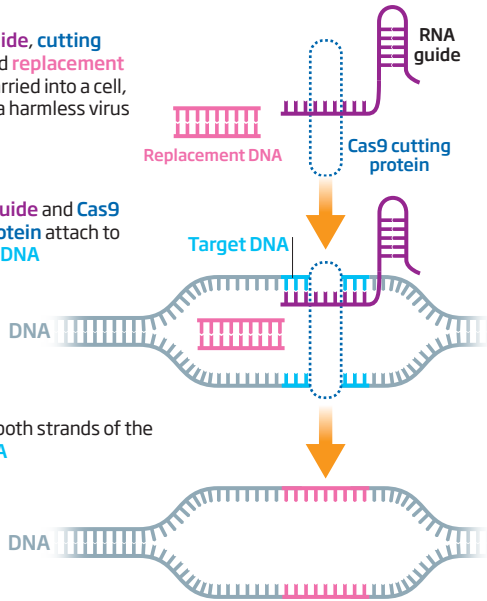
CRISPR allows one or more genes to be edited far more precisely than ever before

An **RNA guide**, **cutting protein** and **replacement DNA** are carried into a cell, usually by a harmless virus

The **RNA guide** and **Cas9 cutting protein** attach to the **target DNA**

**Cas9** cuts both strands of the **target DNA**

The cell's own DNA repair mechanism splices the **replacement DNA** into position. With the right RNA guides and DNA replacements multiple gene changes can be made in a single step



called for a voluntary worldwide ban on any work involving gene-editing of human embryos, even if there is no intention of allowing them to develop. "At this stage the question is whether to go ahead with research," says Gyngell.

A ban appears unlikely. Several UK research organisations and funding bodies have declared their support for research in human embryos. So, too, has an international group of stem cell researchers and bioethicists, called the Hinxton Group, after holding one of the first meetings on it.

It concluded that not only should we leave the door open to germline gene editing, but there is much to be gained from research, including understanding embryonic development and finding out why some women miscarry. "We are all in agreement that this research has tremendous value," says Debra Mathews of the Johns Hopkins Berman Institute of Bioethics, who was at the meeting.

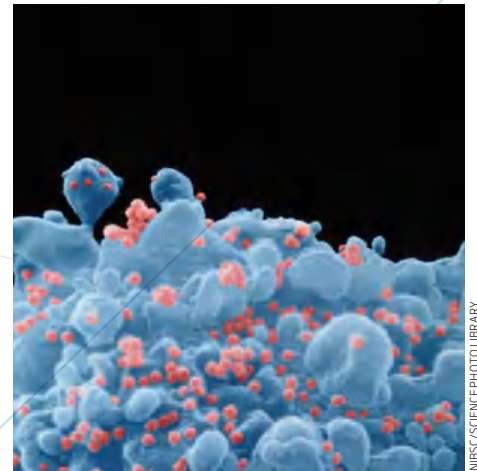
But while germline editing is still decades away, it might not be that long before we start using CRISPR to tweak the genes of adults...

## Will gene therapy go MAINSTREAM?

**G**ene therapy – using genes to treat or prevent diseases – is already saving lives. But it's still very much an experimental treatment used on a few individuals, rather than a routine therapy. CRISPR will help change that.

For starters, it will be much cheaper and easier to develop treatments to the point where they are ready to test in animals and people. And these treatments should be safer. "It's a new age in gene therapy," says Oskar Ortiz of the German Research Centre for Environmental Health in Munich.

Unlike germline engineering (see "Will this lead to designer babies?" page 33), changes made using gene therapy can't be passed on to children. The conventional technique involves adding extra DNA to cells, but there is no way to control where it lands – and if it lands in the wrong place it occasionally results in cancer. With CRISPR gene editing, DNA can be added to a precise spot. Even then it can sometimes be added to the wrong place, but ways to minimise this have already been developed.



What's more, treating some diseases requires altering existing genes rather than adding new ones – and gene editing excels at this. If it proves safe, CRISPR could be used to modify cells in the body to treat a wide range of diseases.

The tricky part will be delivering the gene-editing machinery and new DNA to cells inside the body. Fortunately, biologists working on CRISPR therapies can take advantage of the decades of work spent creating tools for delivering conventional gene therapy. The most popular method is to use harmless viruses called AAVs to carry the new genes into cells.

Viruses carrying CRISPR components have already been used to target genes inside the brains of mice, to find out what those genes do. The drawback is that AAVs can only carry 4700 bases of DNA – and the gene for the key CRISPR protein, called Cas9, is nearly this big (See "How does it work," page 34). That's OK if the aim is just to disable an existing gene. But it won't work for adding genes; there isn't enough room in AAVs to carry both Cas9 and a gene.

## Unexpected problems

There are already some ways around this size limit. Smaller alternatives to the standard Cas9 protein are being tested, for instance. It is also possible to split Cas9 in two, and deliver each half in a separate virus, leaving more room for the rest of the payload. This approach is likely to be less efficient, though, as at least two AAVs have to deliver their DNA to each cell.

Years of animal tests will be needed to ensure that CRISPR-based gene therapy is safe enough to try in people, and Bryan Cullen of Duke University in Durham, North Carolina, cautions that unexpected problems will almost certainly arise when human trials begin. Nevertheless, he is confident that the approach will work: "It will lead to treatments within a decade," he says.

## Could it help **CURE DISEASES** like AIDS and herpes?

Every human has viruses lying low within them. It's highly likely that you have been infected with a human papillomavirus at some point, for example. HPV inserts copies of its DNA into the genome of cells, allowing it to hide away for decades, ready to activate and infect more cells if your immune system slips up. The consequences can be lethal: HPV can cause neck, throat, anal and cervical cancer.

The herpes simplex virus does a similar thing, adding one or more copies of its DNA to sensory nerve cells around the mouth or genitals. And several other common viruses also exploit this dastardly trick to hide away within you.

Until recently, the best we could do was help the immune system suppress any viral activity. With the development of the first gene-editing tools, researchers began to explore the possibility of destroying the viral DNA inside our cells, but progress has been slow and results mixed.

### Huge demand

Now, with CRISPR, the field is racing ahead. Several groups have shown that it is possible to target and destroy viral genes in human cells growing outside the body.

"We are all brimming with excitement," says Bryan Cullen of Duke University, whose team is working on treatments for several viruses, including herpes. "There will be a huge demand if a cure is possible."

It should be easiest to target viruses that integrate themselves into specific tissues in a small area of the body, such as herpes simplex. Could it also work for HIV? The problem, Cullen says, is that HIV hides in memory T-cells, which are scattered throughout the body.

But it might not be necessary to eliminate HIV in all cells in one go, says Kamel Khalili of Temple University, whose team is already carrying out animal tests. Khalili hopes that a series of treatments, in combination with existing antiretrovirals, will allow the immune system to recover to the point that people with HIV can eventually be cured. His team's aim is to make the treatment simple and cheap enough that it can be used in the resource-poor countries that have the most HIV-positive people.



### INTERVIEW

## "IT'S AN ETHICAL RESPONSIBILITY"

Gene editing could transform life, but we need to discuss the ethics of how it is used, says **Emmanuelle Charpentier**, co-discoverer of the Cas9 CRISPR technique

### Now that CRISPR has arrived, should there be a moratorium on editing human embryos?

There have been technologies before that could target specific gene sequences. So the idea of having a technology that would allow biologists to manipulate the human germline isn't new. But the previous technologies were less efficient. CRISPR is very powerful and so easy to use that it is being harnessed for different purposes. It's like any technology: there's a good side to it and there is an ethical responsibility with regard to how to use it.

### How do we decide how to use this technology?

By discussions. There is perhaps a misunderstanding by the public about what the technology does and how it works. It allows more precise genetic changes than all the breeding technologies that have been used before – so the organisms are genetically much cleaner. I think all those around the table discussing the ethics – which includes scientists, clinicians, ethicists and the public – should first understand the technology and that it allows us to accelerate the understanding of the functions of genes. That will be important for the development of

### PROFILE

**Emmanuelle Charpentier** is a molecular biologist at the Max Planck Institute of Infection Biology in Berlin, and the Helmholtz Centre for Infection Research, Germany

biotechnology and biomedicines. Then after that manipulation of the human germline needs to be discussed.

### Is there ever a case for germline editing – altering DNA that can be inherited?

There would be reasons with regard to certain types of diseases. I hope that using the technology with the idea of changing human characteristics will not be pursued. When it comes to using it for therapeutic and preventative purposes – not to change traits that could be inherited throughout the population – then the debate will be for certain kinds of diseases for which maybe the manipulation of the human germline will be considered. But then the question is whether society wants to go there. Philosophically and sociologically speaking, I have lots of issues with this.

### Did you expect your work to cause this debate?

It was unexpected. The findings came a little bit all of a sudden. But it comes down to basic science – CRISPR is a very nice example of how basic science on an obscure immune system in bacteria can potentially lead to powerful technology.

### What do you hope will have come out of your research in 10 years?

I hope that technology will be developed to the point at which CRISPR Cas9 can be delivered in cells and tissue to treat severe human genetic disorders.

### Interview by Catherine de Lange

This is an edited version of an interview given at the Falling Walls conference in Berlin last month. To read the full version visit [bit.ly/NS\\_GeneEdit](http://bit.ly/NS_GeneEdit)



health or the environment, for instance – have proved largely unfounded, but with CRISPR making it much easier to tinker with genes the odds of things going wrong will be greater. It's possible, for instance, that plants given traits such as drought resistance, salt tolerance or faster growth will start spreading and become invasive weeds. Then again, other human activities such as introducing exotic species have already created many invasive weeds and pests.

Another risk comes from something called “gene drives”, which CRISPR is making both easier to create and more powerful. Normally a genetic variant in an organism has a 50 per cent chance of being inherited by offspring. But a gene drive can insert a copy of itself to

“There are fears that gene drives could spread in the wild as a result of lab accidents”

the DNA inherited from the other parent. That guarantees it gets passed to all of the organism's offspring, meaning it can spread very rapidly through a population. In theory gene drives could be deliberately unleashed to wipe out unwanted species such as disease-carrying mosquitoes. But there are fears they could also spread uncontrollably in the wild as a result of lab accidents.

“We need to be careful,” says Austin Burt of Imperial College London, who works on gene drives. But the risk needs to be kept in perspective: we are already causing a sixth mass extinction because our activities are wiping out so many species. Gene drives would affect only one species at a time, and in species that reproduce slowly – like us – they would spread extremely slowly.

The worst-case scenario is that CRISPR is accidentally or deliberately used to engineer a pathogen that infects people or crops – a biological weapon, in other words. But it is already possible to do this in other ways.

The power of CRISPR means it could have huge benefits, allowing us to produce more and healthier food even as the climate changes, and to improve the health and welfare of ourselves, our pets and farm animals. But much depends on this power being used wisely. Or as the uncle of a fictional transgenic creation says: with great power comes great responsibility. ■

Michael Le Page is a reporter at *New Scientist*

## Should we be WORRIED?

**A**fter Dolly the sheep was born, several groups announced they were going to clone people. A bizarre religious cult and a maverick fertility doctor even claimed success in the 2000s, but these claims have never been taken seriously. As far as we know, no clone of an adult human has yet been born, not least because we have struggled to create cloned human embryos.

CRISPR gene editing, by contrast, is relatively easy. It's not the sort of thing anybody could do in their kitchen, but with sufficient money a small team of rogue biologists and IVF doctors could create the first gene edited baby right now. “This is the thing that scares me the most,” says Robin Lovell-Badge of the Francis Crick Institute.

In fact, there is nothing to stop IVF clinics trying germline gene editing in many countries, including the US. “You can easily

imagine clinics trying to boost their revenue by offering this,” says Lovell-Badge, who points out that unregulated clinics offering unproven stem-cell treatments are springing up all over the world.

Such irresponsible behaviour might be disastrous for the health of children – and the purses of their parents – but for now it poses no wider issues. We don't know how to create superhumans even if we wanted to (see “Will this lead to designer babies”, page 33).

The biggest impact from CRISPR will come from the enormous range of genetically altered plants, animals, fungi and bacteria it will be used to create. The technique has already been used to create extra-muscular dogs for police work, hornless cattle for farmers and micropigs for pets.

So far fears about genetically engineered plants and animals – that they will harm our





Graham Lawton goes in search of a strange subterranean predator long mistaken for a mythical beast

# Crouching caver, hidden dragon

**H**ERE'S what you need when you go in search of the world's largest and fiercest cave animal: a hard hat, wellies, a torch, a bottle of schnapps and a lot of patience.

One thing you don't need is anything to defend yourself with. The world's largest and fiercest cave animal is neither very large nor very fierce. Growing to about 25 centimetres long, they are pale, slender and clammy with short, feeble legs, much like a real-life Gollum. They are also virtually blind. So you are more likely die of boredom or cold than come under attack. But what they lack in ferocity, they make up for in strangeness.

I have come to Postojna in Slovenia in search of the olm, *Proteus anguinus* – a rare white salamander that ekes out a slow, silent and very long life in the caves of the western Balkans. Known locally as *loveška ribica*, or “human fish”, because of their pinkish skin and aquatic lifestyle, olms were once only known from specimens washed out of caves by flooding; legend had it they were baby dragons. Now they are Slovenia's national animal. When the country became independent after centuries of French, Austro-Hungarian, Italian, German and Yugoslavian rule, it gave olms pride of place on its coins.

Postojna looks like the sort of nondescript town you would pass through on the way to somewhere more interesting. But beneath the surface it is breathtakingly beautiful. It sits on the edge of the Dinaric karst, a landscape of limestone and dolomite covering much of the former Yugoslavia. Karsts are made of porous, soluble rock and are famous for their spectacular cave systems, carved over millions of years by underground rivers and embellished by the steady drip, drip, drip of water percolating through the rocks above.

Our man descends into Slovenia's spectacular caves for a brief encounter with an olm

Slovenia has something like 10,000 karst caves, but the one at Postojna is the largest. It has been a tourist magnet for 200 years, with around 5 kilometres open to the public. But behind the scenes there's a lot more – around 24 kilometres in total, much of it still unexplored. A 3.5-kilometre section was discovered earlier this year. These quiet, largely unlit sections are the lair of the olm.

## Foot-long megafauna

Our guide takes us through a little-used back entrance at the bottom of a deep sinkhole in the forest. Thus begins a 5-hour trek through some of the most spectacular subterranean scenery in the world, a glorious parade of cathedral-sized caverns and narrow passages festooned with stalactites, stalagmites and flowstones. There are also networks of tunnels blasted by the Italian army between the wars, when the cave passed under the border between fascist Italy and the Kingdom of Yugoslavia. Mussolini visited the cave system in the 1930s and was presumably impressed by its extremely punctual underground railway.

Geology and history aside, we are on the lookout for olms, though chances are slim. Accustomed to darkness and silence, they are spooked by light and noise, and vanish when people approach.

For hours, the only living things we see are bacterial colonies on the walls and the odd cave cricket. Then we try our luck in a low-ceilinged side tunnel that is too young to have accumulated any large stalactites. The mud is knee-deep, the air dank and cold. We pause and drink schnapps, for luck and warmth, and then slowly and quietly approach a shallow pool known to be an olm hangout.

You don't tend to think of small, pallid salamanders as charismatic megafauna,

but in cave terms that is exactly what they are. In this ecosystem they are the apex predator, devouring the equally pale and blind crustaceans that share the darkness with them. There's only one thing that eats olms – other olms (and occasional river fish that get lost in the cave after floods). The males are ferociously territorial.

Nonetheless, life down here is far from action-packed. With no sunlight to fuel photosynthesis the cave ecosystem is extremely low-energy; the only input is organic matter leaching in from the outside world, plus the meagre contribution of bacteria that get their energy by breaking down inorganic molecules. Olms have evolved to go long periods without food – in captivity they are fed just three tiny cave shrimps a day, and can survive quite happily for 12 years without eating anything at all.

The near-starvation diet, cold environment and low metabolic rate may go some way to explaining the olm's extraordinary longevity: they are estimated to live about 80 years on average and may get past 100, a remarkable innings for such a small animal. Olms have long been of interest to gerontologists keen to discover the secrets of eternal youth.

They are biological curios for other reasons, too. Their eyes are vestigial and they lack pigmentation, both classic adaptations to cave life. They are neotenuous, meaning they don't metamorphose into an adult form, retaining juvenile characteristics including external gills and the ability to regenerate their limbs and tails (early experiments trying to force them to grow up failed). Unlike most other salamanders, they are entirely aquatic.



BUCKWINKEL / ALAMY STOCK PHOTO

Their ecosystem is also remarkable, the Amazon of the energy-starved underworld. "We have the richest underground biodiversity in the world," says Tadej Slabe, head of the Karst Research Institute in Postojna. That includes crickets, spiders, pseudoscorpions, snails, millipedes and beetles. Among those are the slender-necked beetle, the discovery of which in 1831 kick-started the study of cave-dwelling creatures, known as speleobiology, and *Anophthalmus hitleri*, discovered in 1933 and named after Hitler (fascist connections are never far away in this part of the world). All are true troglobites, which means they are unable to survive outside the caves.

Olms have been studied for the best part of a century, but there is much that remains unknown. They are presumed endangered thanks to their rarity and the presence of

**Lounging in their frigid lairs, olms can go years without eating so much as a cave shrimp**

threats such as pollution and groundwater extraction, and they are protected. But assessing their numbers is challenging. The standard tool for estimating population size, capture-mark-recapture, is not much use: if you mark an olm by making a nick in its tail or cutting off a toe, the method typically used for amphibians, it just grows back.

So biologists at the Tular Cave Laboratory – another Slovenian karst cave, and a speleobiology lab since 1960 – are pioneering a new technique. Like many aquatic animals, olms leave traces of DNA in the water which can be collected and amplified, revealing their presence and allowing scientists to estimate their numbers even if the ghostly creatures are nowhere to be seen.

Environmental DNA will also help determine whether olms are a single species, or many. One population of olms, discovered in a cave in south-eastern Slovenia in 1986, have black skin and functioning eyes. They are classed as a subspecies but may deserve separate status, which could also be true of other isolated populations. Early results suggest that there could be at least three species, each perhaps numbering no more than a few thousand individuals.

Postojna cave may be home to as few as 200 olms, which makes our mission seem even more quixotic. But at the end of our squelchy slog we are rewarded with a rare glimpse of three of them. They glide sinuously through the water in front of us before swimming away to escape the glare of our torches. Out comes the schnapps, this time in celebration, and we turn back towards warmth and light, leaving the darkness to the creatures that own it. ■

Graham Lawton is deputy editor of *New Scientist*

## Olm on the range

Deep in the underground caverns of the western Balkans lives Europe's only cave-adapted vertebrate – a bizarre salamander called the olm





# BUGGED OUT

Stamping out software glitches is an increasingly impossible task. It's time we learned to live with them, says Timothy Revell



BOTH PHOTOGRAPHS MARC D'ACUNHA LOPES





## A HISTORY OF GLITCHES

**1962** Bound for Venus, NASA's Mariner 1 self-destructed 5 minutes after launch when a coding error sent it off course.

**1982** A rounding error caused the index value of the Vancouver Stock Exchange to lose 25 points a month. By the time it was corrected, it had fallen to about half of its true value.

**1985-1987** A bug in the Therac-25 radiation therapy machine led to six cancer patients being given massive overdoses of radiation, killing three.

**1991** A timekeeping error in a missile defence system at a US military base in Dhahran, Saudi Arabia, stopped it from intercepting an Iraqi missile, killing 28 people.

**1996** An uncrewed ESA Ariane 5 rocket self-destructed less than a minute after launch because of an error in its guidance system. The fault cost \$370 million, making it one of the most expensive bugs ever.

**1999** NASA's Mars Polar Lander was destroyed on its descent to Mars when its software mistook

**T**HE screens stopped working at 3.27 pm. Suddenly, flight controllers found themselves working blind, unable to access key information on the dozens of aircraft in the sky above them. Planes awaiting take-off were grounded and inbound aircraft diverted to other countries. More than 100 flights were cancelled and tens of thousands of passengers were affected. By taking the software out of the loop, and falling back on fail-safe procedures, flight controllers skillfully avoided disaster. But this glitch in the computer system of the UK's National Air Traffic Services on 12 December 2014 could have been far worse.

Software bugs have plagued us since we started to code. They cost the global economy billions, and we spend billions more trying to get rid of them. But they're tenacious. It's common for software to be released with at

atmospheric vibrations as a sign that it had landed. Its sister craft, the Mars Climate Orbiter, was destroyed when it received commands in units of pound-force instead of Newtons.

**2003** North America experienced a blackout because of a bug in the XA/21 monitoring software of General Electric Energy.

**2007** Computers on board six F-22 Raptor jets crashed simultaneously as they crossed the International Date Line, disabling the pilots' navigation and comms systems.

**2009** Google's search engine warned people that every website was malicious, including its own.

**2013** US jury awards \$3 million damages after a buggy engine control system in certain Toyota vehicles is blamed for causing unintended acceleration, linked to at least one fatal accident.

**2015** A bug in Steam, Valve's distribution platform for video games, put some users at risk of deleting all their computer files.

least some bugs – and more are often discovered only once it is out in the wild. At best, these are a nuisance, causing an app to crash every now and then. At worst, they cause serious security and safety risks, or lead companies to lose fortunes. Some have even killed (see “A history of glitches”, left).

In just the past few years, for example, software errors have made Toyota, Land Rover and Ford recall more than a million cars between them for safety reasons. They have crashed spacecraft, let online shoppers buy thousands of dollars of goods for nothing, and even delayed the launch of the Apple watch.

What to do? For a growing number of researchers, it's time to admit defeat. If we can't beat bugs, we need to learn to live with them – switching from damage prevention to damage limitation. Making computers more resilient to things going wrong could mean an end to computer crashes altogether – buggy code or not. “The idea here is immortal software,” says Martin Rinard at the Massachusetts Institute of Technology.

It's not that there haven't been advances. A host of automatic tools now help programmers find bugs by checking their code or running continuous tests. Yet finding them has become harder than ever. As bug-hunting gets better, software gets more complex.

The UK Civil Aviation Authority highlighted the problem in its report on the air-traffic bug: “To test every combination of workstation modes at 1 second per test would take of the order of 100 years, without considering all the other parameters.” Most modern software involves multiple systems interacting, which can lead to unpredictable outcomes and often makes it impossible to track down errors. What's more, looking for bugs can only ever confirm their presence, not their absence. In short, building large, bug-free software systems may be beyond us.

All this means that companies may know that their software contains glitches, but it is too expensive and time-consuming to attempt to find them. Some companies get round this by offering rewards to users who report bugs once software is released (see “Bug bounties”, page 43). But increasingly, researchers are shifting their attention away from removing ➤

## PERFECT PROGRAMS

When you're 400 kilometres up, a software glitch could be disastrous. No wonder NASA has a reputation for careful coding. Hundreds of programmers pored over the code for the space shuttle, specifying what it should do and checking with painstaking rigour that it did so. The team fostered a friendly rivalry between those who wrote the code and those who tested it.

As a result, the space shuttle's code was essentially bug-free. At the time, similar pieces of software, such as air-traffic-control systems, had an average of 11 bugs per thousand lines of code. NASA got this down to just 0.11 bugs per thousand lines - but it cost them \$500 million.

Most organisations cannot afford that level of effort. So what do you do if you need bug-free software without the cost? Instead of hundreds of programmers, some think we should hand the reins over to computers. "Programmers are unconstrained and come up with many different ways to do things," says Marta Kwiatkowska, a computer scientist at the University of Oxford. And when it comes to coding, variety is not the spice of life. "They tend to make mistakes," she says.

Kwiatkowska suggests that we get software to do things for us by writing programs that write programs. The idea, known as program synthesis, is that programmers describe what they want their code to do in precise but relatively simple terms and then have that code automatically generated. To ensure the program that generates the program is itself bug-free would require NASA's level of effort, but this would only have to be done once. Kwiatkowska and others have shown that the technique works for small pieces of code, but it will be some time before whole systems can be built in this way.

Such a handover of responsibilities from humans to software would mirror the shift in the early years of computing, when programmers started writing in human-readable programming languages and let programs known as compilers translate this into instructions that a computer understands. This let programmers focus on the problem that the software was meant to solve rather than the details of how it would do it. Program synthesis allows a similar refocusing.



bugs to simply removing their effects. A bug might lead to a software crash, but it is often the crash itself that causes problems. To address this, Rinard has developed a technique called failure-oblivious computing, which aims to avoid programs crashing at all costs.

When a computer program crashes, it has usually encountered an error that it doesn't know how to handle. In such situations, Rinard thinks the program should just do the easiest thing it can. This might not be the correct solution and might even cause the software to do something wrong, but the result is often better than a full-scale crash.

### Pick a number, any number

Rinard gives an example. Sometimes a program needs to use a number to continue its task, but it cannot find the one it is looking for because of a coding error. It then doesn't know what to do, which causes it to crash. With Rinard's system, this would no longer happen. "We just make up a number, hand it back to the program and surprisingly often the program works just fine," he says.

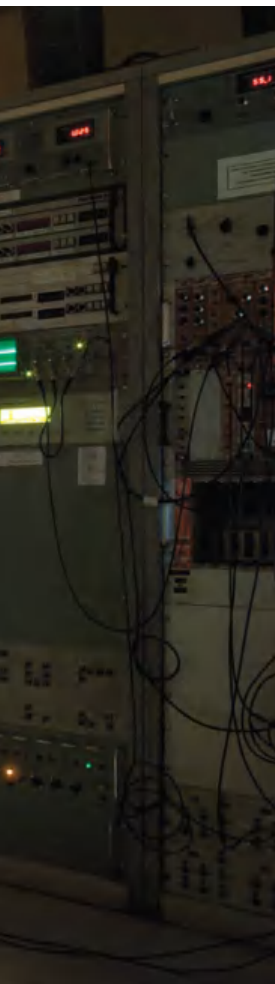
Rinard and his team have looked at many software bugs and found that programs can

normally recover if they can just get past a single stumbling block. "The important thing is that if you see something that is about to take you down and you don't know what to do, then do something very simple but just keep going," says Rinard. "More often than not, the program will take a little bit of a hit, right itself and then keep going."



PATRICK HERTZOG/AP/GETTY IMAGES

At \$370 million, the Ariane 5 bug was one of the most costly in history



## BUG BOUNTIES

By day, Archita Aparichita is a security consultant at a tech firm in Cuttack, India. By night, she is a bounty hunter. Aparichita is part of a global hacker community that tries to break software and gets rewarded for doing it. "It's like playing a really exciting game," she says. "Once they fix it, we find a way to break it."

Hackers such as Aparichita are valued by many organisations because they act as additional software testers once code has gone live. However, not everyone who finds a bug chooses to report it. For example, in 2009, US gambling fan John Kane discovered a way to exploit a bug in video poker machines in Las Vegas casinos to "win" over half a million dollars. So companies such as Google and Facebook give hackers an incentive by offering rewards to those that report bugs.

The more serious the bug, the bigger the bounty. In 2013, Microsoft awarded UK-based security researcher James Forshaw

\$100,000 for finding a bug that let him bypass all the security measures in Windows 8.1. But many are in it just for the thrill, whatever the prize. "They give us money, T-shirts or sometimes stickers," says Aparachita. "It feels awesome when I find a bug."

Still, companies can be unhappy with the methods that bounty hunters use. In 2013, Palestinian hacker Khalil Shreateh found a Facebook bug that allowed him to post messages on anyone's timeline, even if they were not friends. When Facebook dismissed him, he demonstrated the bug by posting a message on CEO Mark Zuckerberg's own timeline.

Facebook refused to pay a bounty because it claimed that Shreateh had violated its bug-hunting rules by hacking other users. Instead, an independent crowdfunding campaign raised money to pay for his efforts. Facebook later apologised, but Shreateh and Zuckerberg are still not friends.

miraculously disappears. You might have lost some work, but at least the same crash is unlikely to happen twice.

Berger's system, DieHard, turns bohrbugs into heisenbugs automatically. This means that if you hit a problem, the next time you try, DieHard will randomly select a slightly different way of running the software that will often avoid the bug. "By making it so that things become a bit more like a roll of a dice, the chances of you having the program work correctly increase," says Berger.

## A second chance

Through a long-term collaboration, Berger has convinced Microsoft to take on board some of his ideas. The Windows operating system now uses a program directly inspired by DieHard called Fault Tolerant Heap, which kicks in when it senses a bug. "If your program is doing well and not crashing, they use their standard approach," says Berger. "But if your program keeps crashing, then the next time you run it Fault Tolerant Heap is used instead."

Systems such as failure-oblivious computing and DieHard run alongside the software they monitor. This means that to run them both uses more computing power than it would to just run the main software. It might seem a small price to pay. But Berger thinks that most software companies today are unwilling to allocate the extra oomph needed to reduce the impact of bugs.

He compares this to the attitude of the car industry in the 1950s and 60s. "We used to only care about horsepower," he says. "We wanted faster and faster cars, but most of the time you don't actually need to use the full potential of your 350-horsepower engine, especially when you're stuck in traffic."

Yet rather than eliminating accidents, we developed seat belts, bumpers and airbags. "Seat belts are added weight and added cost, and airbags are also added weight and added cost, but nobody thinks about that any more," says Berger. "We would prefer to drive safe vehicles."

We want software that does more and does it faster. But rarely do we actually need to use all of the processing power – so Rinard, Berger and colleagues are giving software airbags. "The culture has really changed with the way we put together cars," says Berger. "I think it's time that the culture changed with the way we put together software too." ■

Timothy Revell is a writer, mathematician and computer scientist based in Glasgow, UK

He illustrates the virtues of failure-oblivious computing with reference to the Ariane 5 rocket. Costing \$7 billion, this took the European Space Agency 10 years to make and was designed to take satellites into orbit. However, on 4 June 1996 its software failed, resulting in the rocket self-destructing seconds after launch.

Later investigation found that the control software had tried to store a number in an allocated piece of memory that wasn't big enough. "This caused the main control software to fail and go to the backup system," says Rinard. "The backup system had the same error so shut down as well, causing the rocket to start flying out of control." Once this happened, the rocket automatically self-destructed.

"Here's the kicker," says Rinard. "That number was never actually used. Any number whatsoever could have been used instead and the rocket still flies." If Ariane 5 had been equipped with failure-oblivious computing, it would have been a successful launch.

Rinard's isn't the only new trick in the book. Some think the answer is to limit the injection of human randomness into coding by getting software to write software (see "Perfect

programs", left). Emery Berger at the University of Massachusetts Amherst is taking the opposite tack. He is deliberately injecting a little randomness to get software to crash less.

He's targeting bugs that crash a program in the same way each time. These are sometimes known as "bohrbugs" after the physicist Niels Bohr, whose model of the atom has electrons that orbit a nucleus in a very predictable fashion. For users, bohrbugs are the worst. If you keep doing the same thing on your computer, you will keep getting the same result. Perhaps viewing a particular picture always causes your computer to freeze, or pasting some text always causes your text editor to crash.

But there is another type of bug, known as the "heisenbug". Heisenbugs seem to change when you attempt to observe them and are less predictable than bohrbugs, like the particles in quantum mechanics described by physicist Werner Heisenberg. This means that if you try to reproduce a bug, it often

**"The program will take a little bit of a hit, right itself and then keep going"**



# We, the digital people...

With the rise of the smarter state, its citizens also need to wise up, finds **Pat Kane**

*Smart Citizens, Smarter State: The technologies of expertise and the future of governing* by Beth Simone Noveck, Harvard University Press, \$29.95/£22.95

*Exposed: Desire and disobedience in the digital age* by Bernard E. Harcourt, Harvard University Press, \$35/£25.95

"THE man who wears the shoe knows best where it pinches, even if the expert shoemaker is the best judge of how the trouble is to be remedied." So said the American philosopher John Dewey, defining something of an ideal relationship between government and citizen – or for that matter, company and consumer. The ideal? Listen carefully to what people want, and then expertly fashion policies (and products) to service those appetites well.

The grantees of state and the CEOs of corporate life think they have been "smart" in that way for at least a century. The historical record of both can, at the very least, somewhat dent their professional confidence.

Recently, however, enabled by the internet, the people have raised their game. Hands-on expertise is everywhere. The makers and DIY-ers are on the march. How should mandarins and moguls respond to newly smart consumers and citizens?

Though they come from radically opposed positions, *Smart Citizens* by Beth Simone Noveck and *Exposed* by Bernard

Harcourt shed much light on the balance of state, market and social power in the network age.

As an academic who was an early member of Obama's 2008 back-room staff, Noveck has a sharp take on the current sclerosis of policy-making. She faced a White House bureaucracy that took a year to allow a software upgrade. The Obama newbies might have been "on top of the world", recalled Noveck, "but we were running Windows 2000".

Scarred by this, and by her few sputtering attempts to open the White House to public input, she is now an evangelist for breaking open the circles of jargonised expertise that shape policy. Inspired by Wikipedia, she wants citizens with practical expertise of all sorts to sign up to a networked, searchable "Brains Trust" – named after a group of Franklin D. Roosevelt's advisers who forged the 1930s' New Deal.

Participants will receive points,



ED KASHI/VUI/CORBIS

sometimes prizes, but mostly just the status of being identified by their government as useful to the policy development of the nation. "And who would refuse the White House?" asks Noveck, like the former staffer she is.

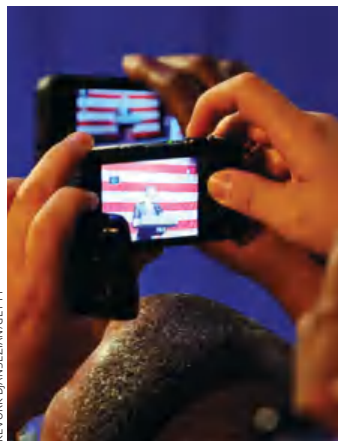
There are millions of Americans who already come together to improve their communities. They would be all too eager to bring their practical smarts to what sounds like the *Huffington Post* for politically active citizens, as Noveck tells it. Beneath the ephemeral Snapchatter of digital living, she assumes that the civil society of Alexis de Tocqueville's 19th-century account of American democracy still pulses away.

But if her Brains Trust were to be embraced, government would get a piece of the action that the likes of Amazon, Google, Facebook and Netflix enjoy. That is, the ability to mine the data interactions of their users, identifying them (and their interests) exactly. "If we can develop the algorithms and platforms to target consumers," asks Noveck breathlessly, "can we not also target citizens for the far worthier purpose of undertaking public service?"

Many would answer: no, we can't, and shouldn't. This is a book with only one passing mention of Edward Snowden's revelations (yes, the US's reputation for "open government" was "lambasted for what many perceived to be duplicity and hypocrisy"). In the light of this, Noveck's wider ambitions here are remarkably naive. Isn't the way the state "targets the citizen" exactly the problem that Snowden raises?

*Exposed* begins where Noveck's imagination falters – at the point where Harcourt writes that "the technologies that end up facilitating surveillance are the very technologies we crave".

With the UK Home Secretary Theresa May's newly announced Investigatory Powers Bill set to pressure service providers to wire in a state-accessible "back door" to all our digital interactions, Harcourt's accounts of recent US revelations will enlighten. But the book's power comes from a readiness to grapple with not just the structure of our super-surveillant, public-private system, but the desires that keep us compulsively interacting with it (as opposed to Noveck's bloodless,



KEVORK DJANSEZIAN/GETTY

Even in Obama's White House, bureaucracy delayed tech upgrades



Creating the “brand called Me” becomes an expected daily task.

It’s not just that this is now all part of an unimaginably vast data stream (in a single day, says Noveck, the world’s data generation is bigger than the entire US Library of Congress). Nor just that it is accessible and searchable by spooks and marketers. It’s that we now live with what Harcourt calls virtual “doppelgängers” – digital versions of ourselves, assembled in the clouds of state and commerce, communicating back to us via adverts or stories that increasingly (and weirdly) anticipate our every desire.

For Noveck, this “matching” of real and digital selves is what enables smarter government, letting officials locate those constructive, energetic citizens that reformers have been waiting for: “less statecraft, more *Minecraft*,” she quips.

Harcourt’s political response moves in the opposite, indeed anarchist, direction. He wants us to reclaim some genuine human privacy, eroded by the infinite desire machines of the info-corporations whose capture of our interactive behaviour is increasingly utilised by the state. Harcourt wants a “leaderless” form of social resistance, using open-source, encryption and small-group meetings, which he hopes will eventually destroy these doppelgängers.

As terror strikes burst across European cities, organised to some degree by “leaderless”, network-enabled cells, it’s a brave call to invoke such techniques to protect us against the all-seeing eyes of state and commerce.

You couldn’t imagine two responses to a smarter state more at odds conceptually. Yet each is plausible in its way. Together, they leave us smarter and sharper about being a digital citizen. ■

Pat Kane is author of *The Play Ethic*, and a curator at FutureFest, organised by UK innovation charity, Nesta

implausibly dutiful citizenry).

Harcourt’s big claim is that we live in an “expository” society. Not only are we exposed to the state and corporations (while they are opaque to us), we also relentlessly expose ourselves to each other,

**“In a single day, the world’s data generation is bigger than the entire Library of Congress”**

through psyche-tickling devices and social tools. He lays out the emotional landscape of our entanglement in digital culture. Networks can offer the illusion of transparency (which Snowden shatters), or an all-too-real seduction – such as the sonorous lulling of an Apple Watch advert promoting a GPS device that can monitor you as easily as a police-issued ankle bracelet.

Our bodily health can be turned into a usable stream of data, the basis for a new “authenticity” built on a highly competitive model of the self. Life narratives spin out easily on Facebook or Tumblr: revelations of our passions and commitments can be precisely tailored there, too.

## A dazzling display

There’s nothing like a parrot to enthrall and delight, finds **Adrian Barnett**

*Parrots of the Wild: A natural history of the world’s most captivating birds* by Catherine A. Toft and Timothy F. Wright, University of California Press, \$39.95/£27.95



IT IS hard not to grin when ring-necked parakeets flash past. Descendants of avicultural escapees they may be, and destroyers

of fruit buds too, but they bring a raucous splash of tropical sound and colour to a drab London day.

In *Parrots of the Wild*, Catherine Toft and Timothy Wright aim for full coverage. Examining the bird’s origins, history, physiology, diet, behaviour and conservation, with sections on intelligence, sociality and their remarkably variable and complex beaks and tongues, the researchers realise their aim splendidly.

In this joyfully but carefully written journey into parrotland, we learn all sorts of marvellous

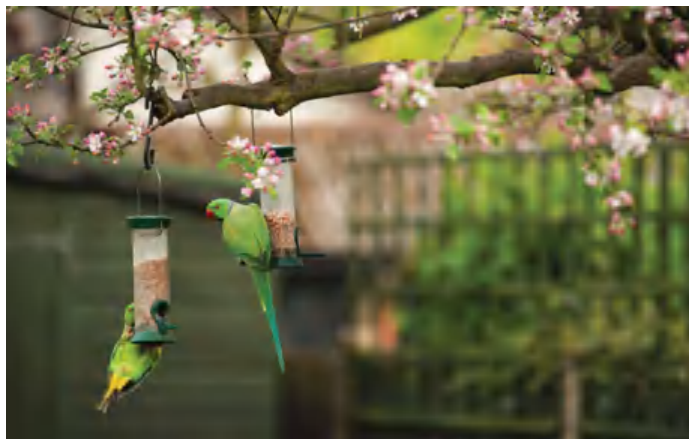
details. Parrots have one of the greatest size variations of any bird group. The hyacinth macaw is 100 times the weight of the thumb-sized buff-faced pygmy parrot, for example. And while Australian lorikeets lap nectar with brush-like tongues, some macaw and cockatoo beaks can focus near-bolt-cutter force.

And there are real surprises – including almost anything about the ecology of the wild budgerigar (also a parrot). It may be one of the world’s most popular cage birds, but its nomadic nature makes budgie research in its Australian outback home next to impossible.

Toft and Wright also tackle the complexities of parrot evolution, revealing that all South American parrots derive from a single 35-million-year-old colonisation. This rapidly radiated into the region’s five major types, including those squawking in my Amazonian garden. A lovely book and fitting memorial to Toft, who died before publication. ■

Adrian Barnett is a rainforest ecologist at Brazil’s National Institute of Amazonian Research in Manaus

**Parakeets now brighten up drab London days**



MALCOLM PARK WILDLIFE IMAGES / ALAMY STOCK PHOTO

# Broken but not destroyed

Can art transform trauma, wonders **Shaoni Bhattacharya**

Trauma: Built to break, Science Gallery Dublin, Ireland, until 21 February 2016

I AM standing on a bustling street corner in Aleppo, Syria. At one side, a group of people chat; above, a young girl's voice carries a song. Until a bang stops her melody dead. Smoke and chaos pour into the street – a barrel bomb has exploded metres away.

Removing the virtual-reality goggles, the adrenaline continues to course even though I was only inside the *Project Syria* immersive for minutes. It was commissioned for the 2014 meeting of the World Economic Forum in Davos to give an insight into life in Syria. And it works. It uses gaming technology and audio from a real bomb blast in Aleppo on 6 November 2012.

This is just one of a number of strikingly diverse installations in the new exhibition *Trauma: Built to break*, at the Science Gallery at Trinity College Dublin, Ireland.

This is no sensationalistic depiction of gore. It is a nuanced attempt to capture insights and lessons from trauma – and even some benefits of it – says Shaun O'Boyle, lead researcher at the Science Gallery. So where we could have peered voyeuristically, the show bravely dissects trauma, teasing out the visceral, the taboo, the hopeful and the inventive. It becomes beautiful, sad, disturbing, humorous... even fun.

Take the memory-laundering booth. Write down a good and a bad memory from the previous week. Place the paper in a safe-deposit box, and retrieve later. The odd word may have been altered, changing the memory.

**Light and dark: a David Cotterrell photo of a field operating theatre**

This is a simple way to show cutting-edge research by Susumu Tonegawa's lab at Massachusetts Institute of Technology, in which mouse memories were revised, recorded and replayed.

"Our brains change memories all the time; they are not reliable at all," says Jessica Stanley, a Science Gallery researcher. This malleability means memories that cause post-traumatic stress disorder may be treatable.

Nearby is *Your Beautiful Self* by artist Naama Schendar, who morphs through multiple people, from a Palestinian mother with a sick child to a London fireman. She lip-syncs to their real narratives, wearing such bizarre make-up and outfits that it negates stereotypes of gender, age and race in the stories.

Confronting trauma can release us from some of its power, says the exhibition's co-curator Daniel Glaser, a neuroscientist and director of the Science Gallery London, which opens next year. He says that seeing is far from

passive, and when you try to avoid looking at something, you are drawn to it. "The not-seen has more power than the seen," says Glaser. "Once you've looked at the trauma for a long time, you can start to get beyond it."

This seems true of many of the installations. Take *Scarred for Life*, which features colourful prints of scarred body parts juxtaposed

**"Once you've looked at the trauma for a long time, you can start to get beyond it"**

with photographs of their owners. Many are humorous, like the woman looking mock-askance at her own arm stump, painted red. Artist Ted Meyer wanted to focus on how we heal and survive after physical trauma. Of the 100 people he worked with, 99 reported being stronger after their trauma.

The exhibition also explores societal trauma. A black-and-white photo of a desolate council estate in Northern Ireland takes

on a different meaning once you read the work's title: *Silence, After a Kneecapping*.

In contrast are David Cotterrell's visceral photographs taken in an army field hospital in 2007 in Afghanistan. In the most graphic, a gash runs the length of a soldier's calf, and his foot is split open. All the patients he contacted wanted the photos displayed because they helped bridge gaps in their lives, he says: they could not describe why they were different after returning from war.

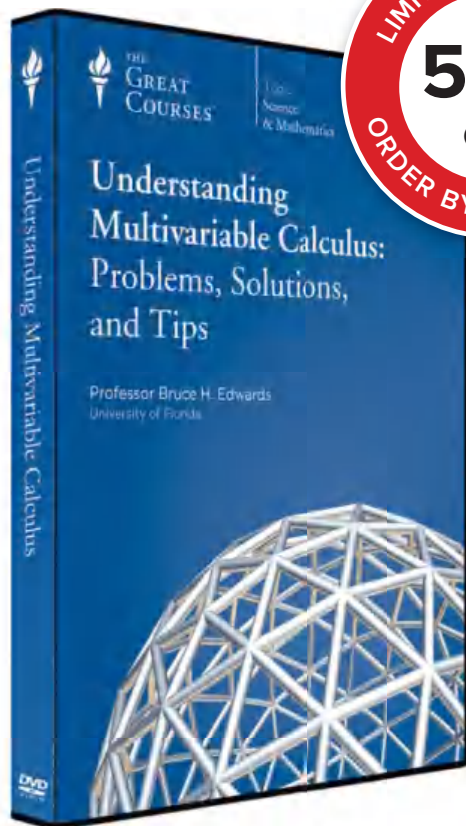
The Science Gallery wants *Trauma* to start a conversation. This innovative and thoughtful show will do that and more by pressing emotional buttons while asking how we process trauma and emerge with something new. Such catharsis will be needed, with last month's events in Paris and Mali showing how personal and collective trauma are never far away. ■

Shaoni Bhattacharya is a consultant for *New Scientist* based in London



SIGHTLINES: JUSPERNUMERARY; DAVID COTTERRELL/TRAUMA: BUILT TO BREAK/SCIENCE GALLERY





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25. Triple Integrals in Cylindrical Coordinates
26. Triple Integrals in Spherical Coordinates
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28. Curl, Divergence, Line Integrals
29. More Line Integrals and Work by a Force Field
30. Fundamental Theorem of Line Integrals
31. Green's Theorem—Boundaries and Regions
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Informal discussion may take place with the Academic Registrar, Dr Valerie Shrimplin, Gresham College, Barnard's Inn Hall, Holborn, London EC1N 2HH, Telephone 020 7831 0575, [v.shrimplin@gresham.ac.uk](mailto:v.shrimplin@gresham.ac.uk)

**The closing date for application is 14 January 2016.**

**Interviews will be held in London on 29 February 2016.**



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## EDITOR'S PICK



## Open minds and quantum boxes

From Richard Marsden

A wide range of possible interpretations of quantum mechanics were considered at the Vienna symposium on Emergent Quantum Mechanics, as Michael Brooks reported (14 November, p 14). Howard Wiseman and Jan Walleczek both spoke of the importance of keeping all possible interpretations in mind.

It seems to me that these quantum theories are all in a state of superposition. With our current understanding of quantum mechanics as a "black box", all of them are possible. By opening the box and making an observation, the wave functions for these theories collapse into the one underlying quantum theory. Wichita Falls, Texas, US

From Bob Bath

It occurs to me that one option for obtaining the most useful explanation for the weirdness of quantum theory might be to put all the researchers into a box and take the lid off every now and then. The one that appeared at the top most often would get my vote.

Northcote, Victoria, Australia

To read more letters, visit [newscientist.com/letters](http://newscientist.com/letters)

## So how do you bribe an algorithm?

From Steve Dalton

I found Anil Ananthaswamy's review of *The Master Algorithm* fascinating (31 October, p 44). I couldn't help wondering whether the algorithm, along with all its threats of replacing people's livelihoods, might also have detected FIFA's obvious corruption, doping in major sporting events and the hand of vested interest in political policy, among many other things.

If it were capable of doing this, and we were all still allowed freely to know about it, then it may be a different world that results, but one I'd happily leave to my son. Chipstead, Kent, UK

## A dangerous climate myth

From Ruth Jarman

I was surprised by your article stating that "analysts say that pledges put the world on a path to halt global warming at 2.7 °C" (31 October, p 6).

As we increase global temperatures, natural processes, such as melting of sun-reflecting icecaps and burning up of tropical forests, take over. Temperatures escalate still further.

The thinking that humanity will still be in control of climate change if temperatures rise more than 2 °C is a dangerous myth, and one that I would hope you would do your best to counter.

Hartley Wintney, Hampshire, UK

## Animals more than meat expectations

From Jan Horton

Meat might, perhaps, be replaced by the vat-grown products you describe (31 October, p 10). But it is not the only useful "product" of

livestock. In Australia, animals are reared on crop residue. Without the animals, these residues would have to be disposed of by other means before another crop can be grown – often by burning.

Livestock also eat weeds and pasture, minimising the use of weedkillers. Dung is then broken up and moved into the soil by dung beetles, for example, maximising fertility and improving soil structure for crops. Raw crop residue turned into the soil takes much longer to break down. Growing crops without animals upsets a large number of natural processes.

We don't even need to use emission-intensive ruminants to produce meat. Kangaroos, for instance, produce less carbon dioxide for the same amount of meat. We know how to farm them, and they are delicious. We need to take them off our coat of arms and put them on the dinner plate. West Launceston, Tasmania, Australia

## Agriculture is not a higher state

From Kate Fletcher and Corwen Broch

In your article on the multiple inventions of farming, we were disappointed to see agriculture equated with civilisation (31 October, p 31). This myth has been used for hundreds, perhaps thousands, of years to justify the seizing of land from non-agriculturalists, as well as their forced "resettlement" and even genocide against them.

People who hunt, fish or graze animals for their living are not backwards or representative of an earlier stage in human progress. These ways of life are simply alternative adaptations to different landscapes and to different cultural preferences. Modern non-agriculturalists are just that, modern people who simply base their economy on a

different (often more sustainable) way of deriving economic value from the land.

The premise that hunter-gatherers are unrooted is another myth. The first villages and permanent settlements appear around the world long before the adoption of farming. In fact hunter-gatherers, fishing people and herding people are extremely rooted, dependent on their intimate knowledge of the landscape for their livelihood. Frome, Somerset, UK

From Beth Gott

Bob Holmes put forward the idea of "proto-farming" – hunter-gathering peoples acquiring detailed knowledge of desirable vegetable and animal foodstuffs.

It was not until the invasion by Europeans that agriculture was brought to Australia, with its varied landscape ranging from the tropical north to the temperate plains and the dry sclerophyll forests and semi-deserts of the centre and south.

Before this, largely by the intelligent application of fire, Indigenous Australians managed the landscape to provide all the necessities of life. If one asks why the first Australian people did not "invent" full-blown agriculture in over 40,000 years of occupation, the simple answer is that they didn't need to. Their practices were sufficient to provide for their needs. So does this deserve the designation "proto-farming"?

For too long we have viewed agriculture as a higher level of human evolution. It has drastically reduced the biodiversity of Australia. Clayton, Victoria, Australia

## Spinach's spoof story spreads

From Will Christian

Thanks to Chloe Lambert for an excellent article on the effects of modern farming techniques on



## f "So are you saying that weekend mortality correlates with lower staff numbers?"

Dobra Sekaninova wants to get down to basics over mortality among infants born in UK hospitals at the weekend (28 November, p 8).

the nutritional content of food (17 October, p 32). Unfortunately, though, she perpetuates the urban myth that spinach was once thought to have 10 times its actual iron content.

Mike Sutton debunked this in 2010 and traced it first to a humorous article by T.J. Hamblin in the *British Medical Journal* for Christmas 1981 (see [bit.ly/SpinachJoke](http://bit.ly/SpinachJoke)). The claim was that a 19th-century error in the placement of a decimal point led to the iron content of spinach being overestimated by a factor of 10. This, Hamblin suggested, led cartoonist Elzie Segar to choose spinach as the source of Popeye's superhuman strength.

Then Sutton traced the error back further, to a professorial inaugural lecture by Arnold Bender in 1972 (see [bit.ly/SpinachJoke2](http://bit.ly/SpinachJoke2)). Perhaps early studies confused wet and dry spinach, but there is no evidence for a decimal point error, nor that one influenced Segar. Early Popeye cartoons demonstrate that Segar chose spinach for Popeye for its vitamin A content. *Bristol, UK*

## Where should you file this letter?

From Mark Harvey

I am sure I am not the only person to find themselves in a dilemma after reading your interview with Sharon MacDonald about what our culture should keep (24 October, p 28).

I enjoyed it enormously: so much so that I now think I should save the article. But should I keep the whole magazine, download the article, or print it off? *London, UK*

## Zombie professor seeks teaching job

From Eric Kvaalen

I am sure that John Hastings was conscious when he prepared his lectures (Letters, 17 October). But his contention that he had to be is not convincing.

We already have computer programs that teach, and programs that learn. Some day we may have programs capable

of giving lectures as he did, but without being conscious. They may even act as though they are conscious, but would simply be "zombies".

*Les Essarts-le-Roi, France*

## The search for roots of stories

From Jill Charles

I enjoyed your articles on the fantastic voyages followed by various atoms and molecules (14 November, p 30). It would have been good, though, when tracing these histories, to acknowledge a debt to Primo Levi's book *The Periodic Table* – in particular the short story *Carbon*.

*London, UK*

## Do not overrate that old Fraud

From Gary Myers

As an associate fellow of the British Psychological Society I was surprised to read as part of

Sumit Paul-Choudhury's discussion of the shortlist for the Samuel Johnson Prize for Non-Fiction that "other threads of science ran through the books – the influence of Freud for example" (31 October, p 45).

Assuming that this was not a reference to Freud's early work as a neurologist, it is worthwhile to remember that the philosopher of science Karl Popper used Freud's theory of psychoanalysis as a prime example of pseudoscience.

The philosopher Ludwig Wittgenstein's *Lectures and Conversations* records this: "Freud is constantly claiming to be scientific. But what he gives is speculation – something prior even to the formation of an hypothesis." *Ilkley, West Yorkshire, UK*

The editor writes:

■ Freud's work might not have been scientific, but his influence was and is of importance to science.

## For the record

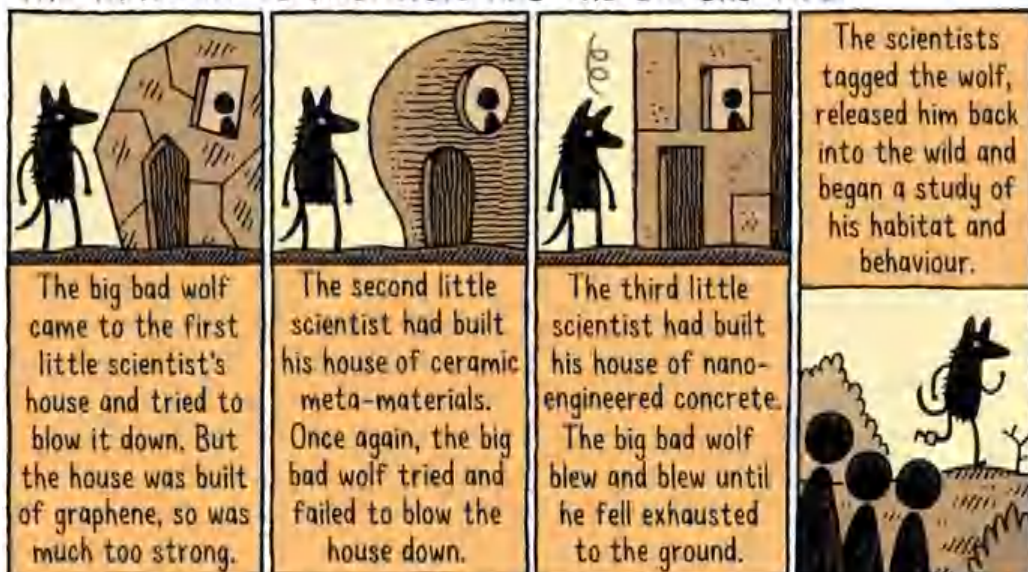
- It stings: Eva Gross leads the team using chilli gas to deter elephants (21 November, p 22).
- The researcher exploring the quirks of friendship was Hans Alves (Feedback, 21 November).
- Dam! The Scottish Natural Heritage report on beavers author was Martin Gaywood (21 November, p 10).
- The free online cognitive behavioural therapy package tested by Simon Gilbody and his colleagues was MoodGYM, made by the Australian National University Centre for Mental Health Research (7 November, p 40).

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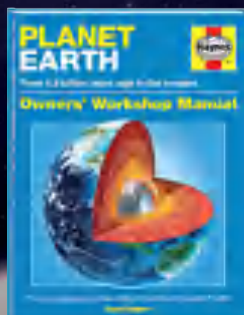
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JUST the thing for card-carrying members of the alternative-medicine scene: Richard Cote was recently given a "very special" piece of card, with instructions to tape it to the outside of a clear bottle of water. The water would then read the number on the card and dutifully rearrange its structure to become charged with special healing properties.

The font of this fruitlooper is Source Energy Medicine, and it inevitably derives from the theories of Masaru Emoto, the Japanese researcher who claimed that writing disparaging labels on saucers of freezing water can influence the shape of the ice crystals (1 July 2006).

Feedback thinks that pharmacists would be greatly inconvenienced if they no longer had to dispense medicine, and could simply give customers the labels instead. "Unfortunately, there's only one charge per card," writes Richard - although how the water knows whether a card has been used before is anyone's guess.

The healing power of these labels is not just for people, either. A visit to [sourceenergymedicine.com](http://sourceenergymedicine.com) shows

that you can also buy species-specific cards for "cats, dogs, horses, llamas/alpacas and honey bees". Gerbils, cows and butterflies will have to stick to plain water.

WINTER is coming to the north, with the UK bracing itself for several months of wet and windy weather. To counter the threat of floods, the Environment Agency recently dispatched two giant pumps to Cumbria in north-west England. *The Guardian* newspaper reports that these boast the curious ability to move 120,000 "cubic litres" of floodwater per minute.

Why the water must be boxed up before pumping isn't clear, but the description trickles in from several other news agencies, hinting that many buckets have been drawing from the same well. However, the press release issued by the Environment Agency bears no trace of diced water.

The question remains: how do they get the cubes of water to go down circular pipes?

OUR inbox is likewise deluged... with suggestions of nominative determinism. Peter Dawe says: "Not only is the National Trust's coast and marine adviser Phil Dyke working on flood issues, he is also promoting a policy that involves filling dykes."

FURTHER examples pop up like weeds in Feedback's manicured lawn: a UK parliamentary discussion on progress made in eliminating the invasive Japanese knotweed plant featured a contribution from none other than baroness Gardner of Parkes.

ANOTHER mislabelled solution: the BBC's World Service reported that a 156-year-old maths problem had been solved by a little-known Nigerian scholar, Opeyemi Enoch. The Riemann hypothesis - a description of the expected distribution of prime numbers - is one of the most important problems in mathematics. Whether it is true is literally a million-dollar question, such is the bounty that the Clay Mathematics Institute (CMI) is offering for a solution.

The claim first appeared in the Nigerian newspaper *Vanguard*, which also reveals that Enoch "previously designed a Prototype of a silo for peasant farmers and also discovered a scientific technique for detecting and tracking someone on an evil mission".

Surprised mathematicians were quick to point out that the story did not add up, and at the time of writing, the CMI website still lists the Riemann hypothesis as "unsolved".

SPEAKING of empty results: does nominative determinism count when it involves nothing at all? Critic and writer Christopher Null finds that his surname makes him invisible to machines, with many programmed to ignore it - such as those of his bank. The easiest solution, he writes, is to add a full stop: "This not only gets around many error blocks, it also adds a sense of finality to my birthright."

IS NOTHING safe from the UK government's proposed ban on all things psychoactive (20 June)? Having

read Chloe Lambert's feature on how gut microbes can influence our thinking (21 November, p 30), Jem Moore worries that the dairy counter is next on the hit list. "I hope no one tells the government about *Lactobacillus rhamnosus*, otherwise bioactive yogurts will be banned too," she says.

Feedback hopes the bill will curdle before it can be enacted, but readers may be wise to stock up on yogurt all the same.

WALK this way: Bernard Morcheles was browsing the web for a brace to improve his posture. He found many that offered magnets to boost circulation and so forth. "Knowing these options are fruitlooper, I decided to buy one anyway purely because the writer of the descriptive copy has such a great sense of humour," he writes.

Bernard points us to the "Posture-Corrective Therapy Back



Brace with Magnets" on Groupon, which boasts that "magnets sewn within the brace's breathable fabric strive to retune disrupted magnetic impulses that can lead to aches, discomfort, and a desire to head to the North Pole".

"The brace doesn't correct my posture but it does remind me to stand up straight," reports Bernard, adding that "the magnets must work since I have no desire to head to the North Pole".

You can send stories to Feedback by email at [feedback@newscientist.com](mailto:feedback@newscientist.com). Please include your home address. This week's and past Feedbacks can be seen on our website.

Chris Whitfield reports his friend receiving a T-shirt from an African elephant conservation charity: "Their slogan is now displayed across her ample bosom - 'Make space for giants.'"

## Nettling conundrum

Can any readers identify this object (see photo) growing on a stinging nettle of the species *Urtica dioica*? The nettle was beside a gravel drive, and there are some small patches on the underside of the leaf ribs.

■ Such orange-red swellings on the stinging nettle's stem, which tend to cause it to curve, are the result of an infection by the fungus *Puccinia caricina*.

Small orange cusps are found on the surface of these deformations, or galls. These contain one of the several different types of spore that this fungus produces. *Puccinia* is a representative of the group of fungi known as rusts. But in contrast with fungi such as mushrooms, which feed on dead or decaying organic material, rusts infect living plants and are known as obligate parasites – organisms that cannot complete their life cycle without exploiting a suitable host.

Members of the rusts cause diseases in many cereal crops, and have extremely complex life



galls on the leaves and berries of the redcurrant.

Frank Wuytack  
Herent, Belgium

## Waning woodpile

Sometimes the wood at the bottom of our woodpile decays to the point where it has only a small fraction of its previous dry mass. What has happened to it? Where did all the carbon go? From the point of view of greenhouse gas emissions, is it better for the wood to be burned in my fire or for it all to rot back into the earth?

■ Dead wood is first converted into living biomass, mainly through the actions of fungi, other microbes and woodlice. Eventually, it ends up as carbon dioxide, methane, water and

nitrogen, plus minor quantities of mineral solids, most of which eventually wash away or remain in the soil as fertiliser.

However, in terms of greenhouse gas emissions, rotting offers advantages despite its release of methane. Fire abruptly converts almost all the carbon into CO<sub>2</sub>, whereas detritus feeders and agents of decay leave some combustible materials, such as lignin and humic acids, that act as buffer stores for carbon.

Those stores last for years, accumulating in the soil as solids rather than in the air as CO<sub>2</sub>. It would take the CO<sub>2</sub> from burning a long time to settle down innocuously like the trapped residues produced by the wood rotting.

There is no simple global limit

to how much carbon such storage could accumulate. Its only rivals for sheer magnitude would be the deep-sea accumulation of dissolved CO<sub>2</sub>, and carbonate minerals and soils in places such as chalk cliffs and downs.

Jon Richfield  
Somerset West, South Africa

## This week's questions

### DINOSAUR DNA

I recently watched the movie *Jurassic Park* and its sequels, in which DNA from the stomachs of mosquitoes stuck in amber was used to recreate the dinosaurs. Could you do this in real life?

Joseph Scott (age 10)  
Stonehaven, Aberdeenshire, UK

### UPRIGHT SNOOZE

Why do some animals, such as humans, lie down to sleep, whereas others, such as elephants and giraffes, stand?

Martie van der Walt  
Pretoria, South Africa

### A BED OF ROCKS

Railway sleepers often sit on a bed of small stones that act as ballast. This ballast material stretches well beyond the width of the sleepers and to quite a depth. But why does it have to be stones? Could anything else be used either physically or economically?

Peter Brigg  
Queensland, Australia

## "Members of the rusts cause diseases of cereal crops and have extremely complex life cycles"

cycles that often involve different host species.

In the case of *P. caricina*, another host in addition to stinging nettles is the grass-like sedge plant, and it also forms

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